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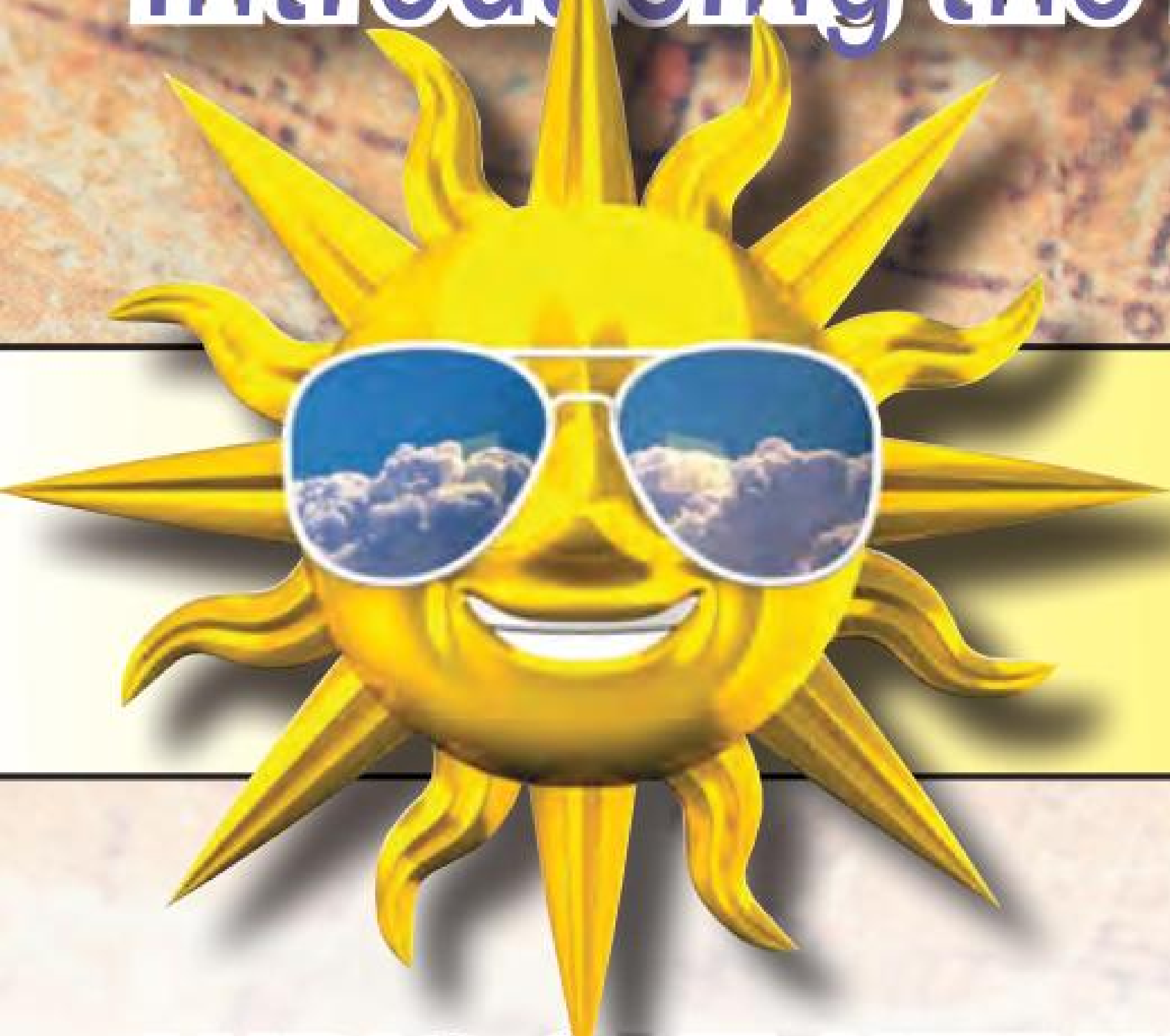

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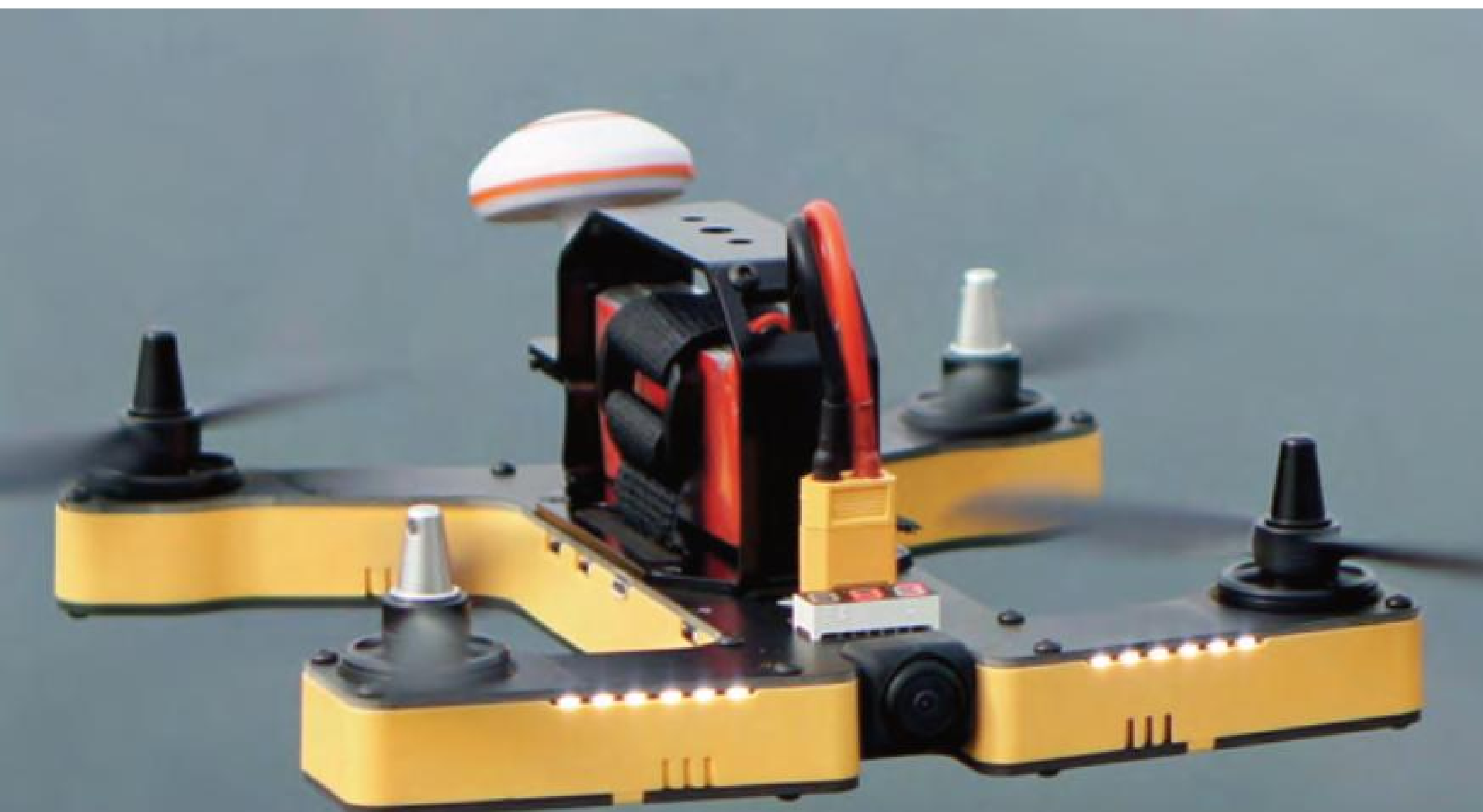

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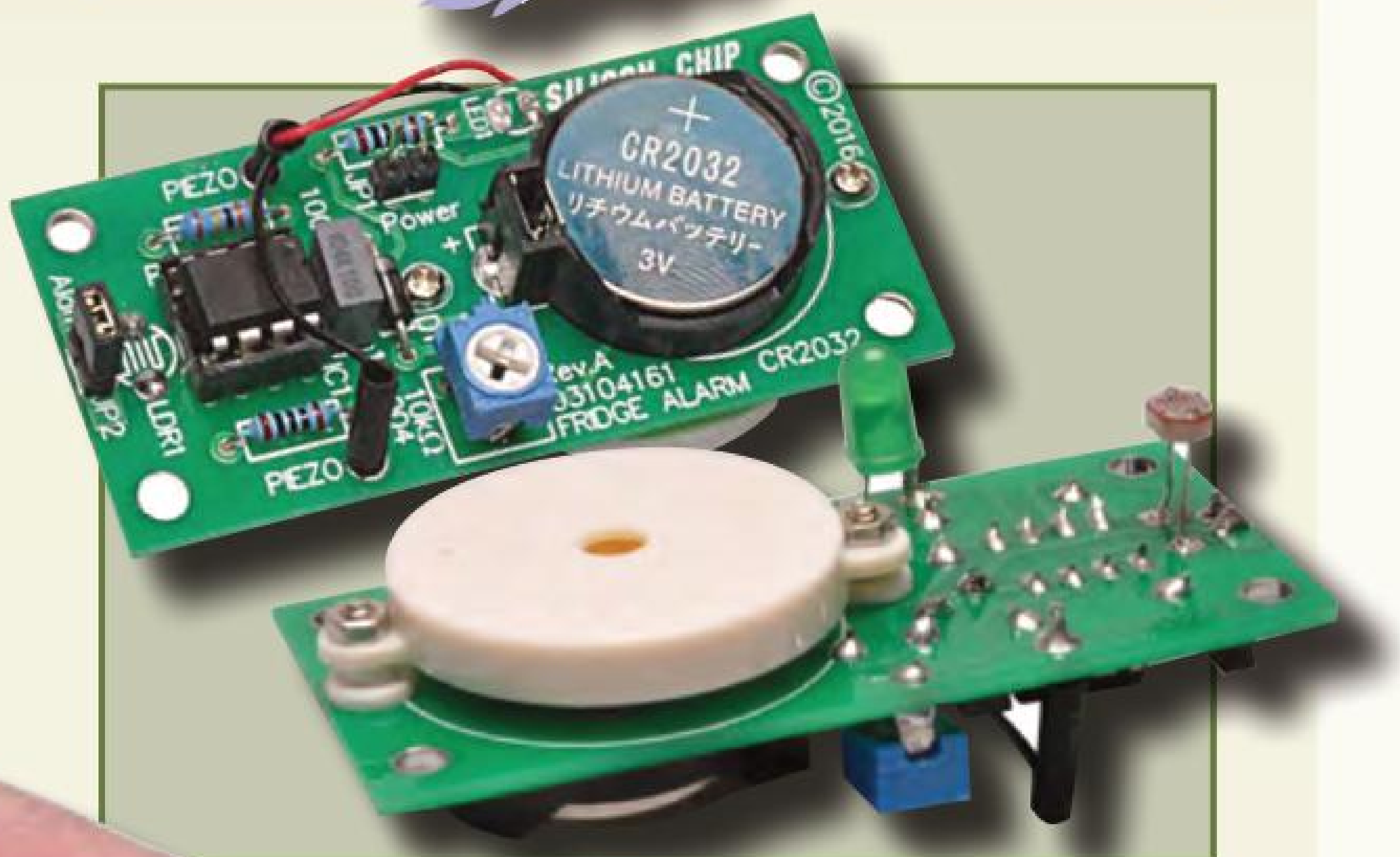

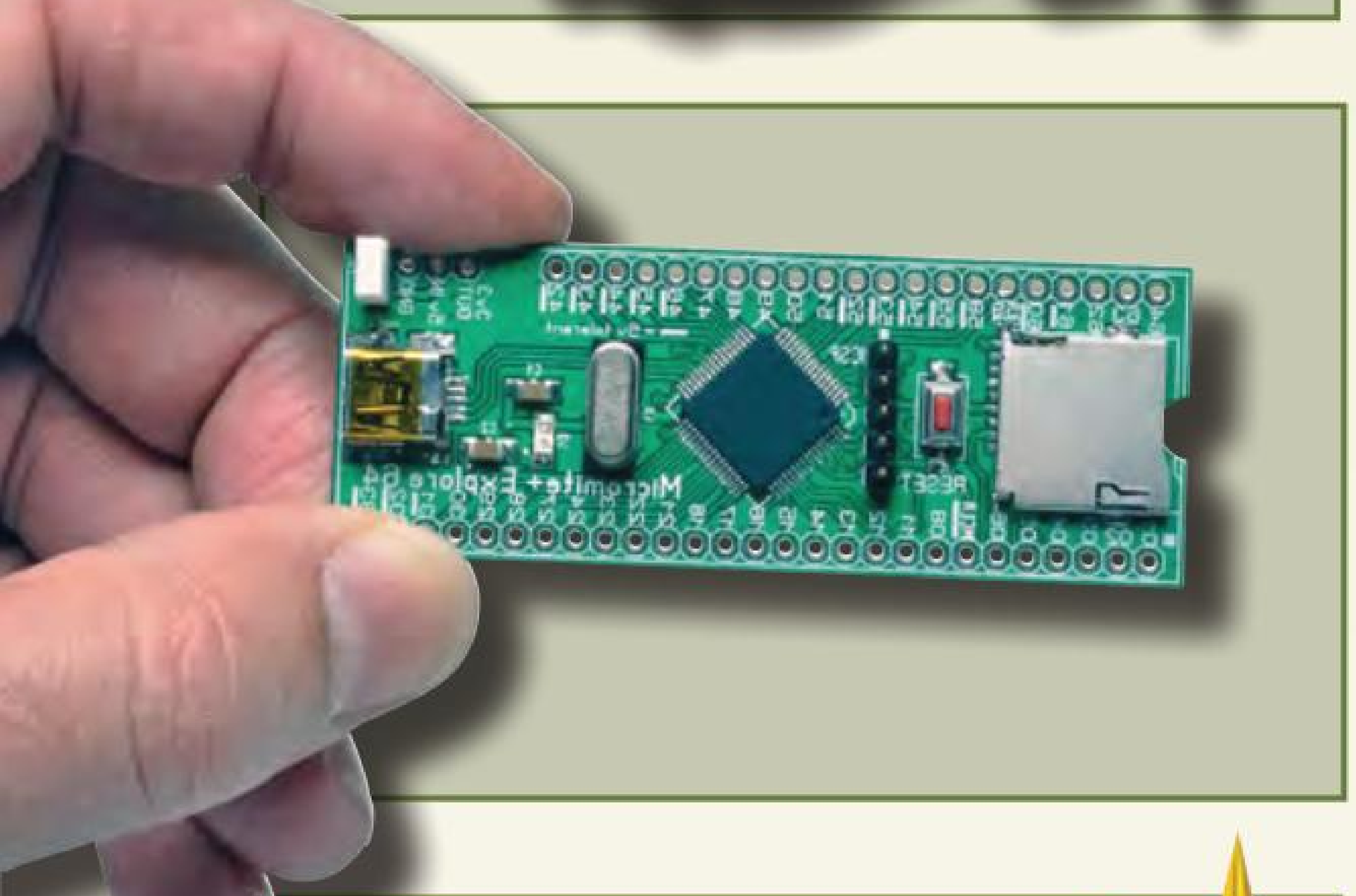

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Our September 2017 issue will be published on Thursday 3 August 2017, see page 72 for details.

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*Assembled Order Code: AS8157 - **£49.96***

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*Assembled Order Code: AS3108 - **£89.95***

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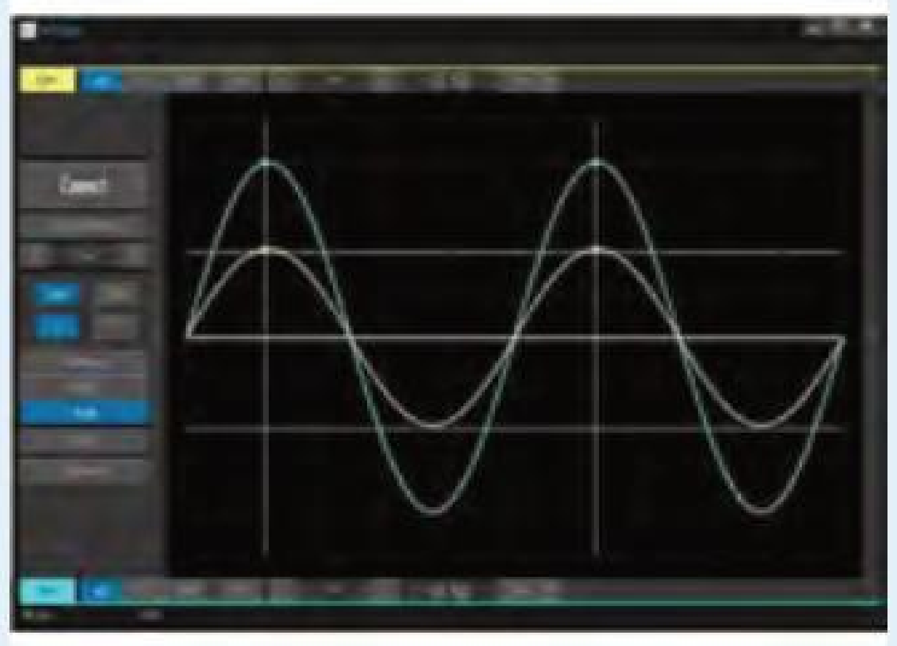

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Bargains galore!

As I write – 21 June – it's not only the longest day of the year, but also the BBC News website has just reported that 'The UK is basking in its hottest June day in 41 years, with a temperature of 34.5°C (94F) recorded at Heathrow.' Given that, it may well be that sitting indoors melting solder is the last thing on your mind. But this is a British summer – grey clouds and rain are definitely just around the corner and then you'll need something fun to occupy a damp weekend!

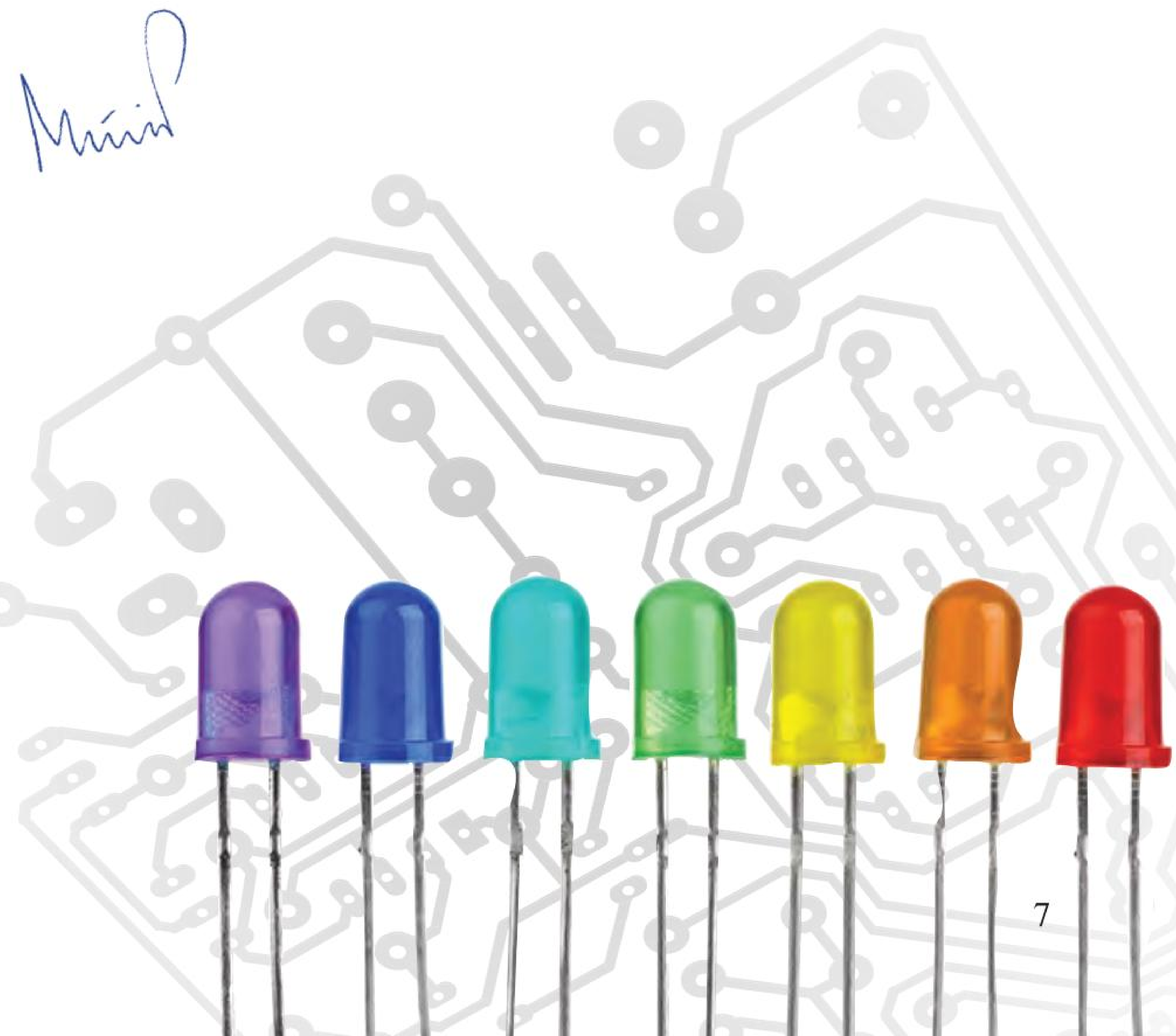
Naturally, this issue has the usual bumper crop of great features and fascinating projects to keep you busy, but please don't skip the adverts, because we also have a quartet of not-to-be-missed free and on-sale items. First out of the starting blocks is our very own *Super Summer Sale*, with great discounts on PCBs, *EPE* back issues (paper and CD-ROM) and *Teach-In* bundles. Plus, if you spend over £100 we'll throw in a free PICkit 3 from Microchip! See page 5 for the full money-saving details.

Talking of Microchip, don't forget that in every issue they generously run a free-to-enter competition where you can win some fantastic PIC-oriented equipment. This month, page 27 explains how to win a PIC32MK GP Development Kit.

Next up, on page 39, we have a couple of great prizes from our friends at **micromite.org**: a fully assembled *Explore 64* and a *Micromite LCD Backpack kit*, complete with 2.8-inch touchscreen. Never heard of the E64? Well, you're in luck, because we explain how to build and use this great product in this issue.

Last, but not least, Farnell element 14 is offering you the chance to win one of three complete Raspberry Pi desktop computer kits. So, page 61 is a must for all you R-Pi fans out there.

We can't promise sunshine, but whatever the weather, we will keep you entertained, informed and at the cutting edge of electronics!



NEWS

A roundup of the latest Everyday News
from the world of
electronics

Nits and smart pixels – report from the DTG *by Barry Fox*

The Digital TV Group (DTG) is a self-funding UK collaboration centre for innovation in digital media technology, which was set up in 1995 with the purpose of looking after the digital TV marketplace. It underpins the free-to-air platforms Freeview, Freesat and YouView, and supports the development of pay-TV and other platforms.

I attended the 11th DTG Summit, held in May. For much of the meeting, a stream of speakers stated the obvious: nobody knows the extent to which OTT (over the top) online streaming will replace over the air broadcasting, or on what timescale.

Anne Bulford OBE, the BBC's deputy director general, opined (pointlessly): 'We have to be more responsive in how we respond'.

Thomas Wrede, VP reception systems at satellite operator SES Astra, reminded the audience that the mobile industry enjoys a huge advantage over broadcasters; people expect to change their handsets every two years but TV viewers expect to keep their sets for at least five years, and usually longer. 'If people changed their TVs every two years, WOW what we could do?', Wrede mused.

Arguably the most colourful opinion came from Jonathan Thompson, CE Digital UK: 'If anyone else tells me TV is dead, I will kill myself!'.

The nit view from Dolby

Among so much soft waffle it was a refreshing to hear Pat Griffis, VP technology, office of the CTO, Dolby Laboratories, talk hard tech fact about HDR (high dynamic range) video.

'The nits race is on, have no doubt about it,' he said, before delivering a masterly 'thesis' on how HDR makes pixels 'better' and dynamic metadata makes them 'smarter' – to deliver better HDR to homes with HDR TVs, map HDR to SDR (standard DR) for homes still using legacy sets and make artistic content look consistent over a range of devices from TVs to mobiles. Griffis then rebuffed 'what a lot of people say' about the practical difficulties of using dynamic metadata with live broadcasts.

Modern displays continue to improve their brightness, measured in 'nits' (candela per metre squared) and dynamic range, but broadcasters must still cater for less bright legacy systems with standard dynamic range.

'The challenge we have is that production technologies are continuing to improve, towards an aspirational goal set by SMPTE (Society of Motion Picture and Television Engineers) of 10,000 nits (the colloquial term for candelas per metre squared), but today's SDR delivers around 100 nits'.

'However, display technology is continuing to advance. We are getting closer to what the human eye can see. Remember that every time you open your eyes you see HDR. We are already seeing consumer displays of 1800 nits from Sony, which is 18-times brighter than legacy displays, and we can expect to see even brighter consumer displays in the future'.

This was particularly intersting because Sony has so far refused to put a brightness figure on its new TVs.

Holding up a mobile, Griffis said, 'This LG phone supports HDR and is in the market today. The future is here and it will continue to advance'.

He continued by explaining that the 'classic way' to down-convert HDR to SDR was with a 'static curve', which is 'blind to the picture content' and works unsatisfactorily because 'it knows nothing about the content (and) is like deflating a balloon'. A better way, he said, is to 'look at the content' by measuring 'the brightest, darkest and average picture content'.

'When mapping HDR to SDR you get a better result from knowing the content; capturing the maximum, minimum and mid.

It's the content, stupid

Griffis continued, 'It not only improves reproduction quality but make re-rendering more consistent across devices, so that the artistic look is very similar regardless of whether it's a TV set or mobile device.'

'There are already a hundred movies that have been graded this way using 'smarter pixels content', for Vudu, Amazon and UHD Blu-ray titles.'

'But what about live?' he asked rhetorically, 'Live is the tough one because you are switching sources quickly. We have heard a lot of people say, 'you can't use this kind of content mapping approaches with dynamic metadata because metadata doesn't work in a broadcast facility'. We are well aware of that, and the proposal we have put on the table and talked to many broadcasters about is that just before the (broadcast) encoder you generate the metadata, in near real time, with one frame delay, and then combine it with the content. The device does the analysis just before the

Nits and smart pixels – report from the DTG – *continued*

encoder. It's compatible – Dolby is codec agnostic. This is what we use already with all the major editing tools. It's well proven technology. The key was to make it work in near real time for broadcast.'

'No metadata needs to be harmed, contrary to what some people may be saying. It's derived just before (broadcast) encoding.'

Smarter and better

'So the bottom line is that I like to think of this dynamic metadata as making the pixels 'smarter'. HDR makes them better, dynamic metadata makes them smarter.

'Google's Chromecast supports these kinds of concepts. There are hundreds of smart-pixel titles from Hollywood in the market. Netflix Originals will be moving to this approach, with Amazon, Vudu and Blu-ray.'

There was one hard fact notably missing from Pat Griffis' talk. When Dolby first talked about HDR, there was talk of dynamic metadata adding around 20% more bits to the bitstream, which is not what bandwidth-strapped broadcasters want.

Speaking a couple days later at a MESA (Media and Entertainment Service Alliance) event, Simon Gauntlett, Dolby's director of imaging standards and technology (ex-DTG) acknowledged that 'metadata is a bit of a dirty word when you are working live,' and explained, 'we are learning a lot as we do experiments. When delivering metadata to the home you could do it frame by frame, but in general people tend to do it scene by scene to avoid transition jumps. It varies with the content. It could be as low as 5% or it could be as high as 10% to 15%. We don't know yet'.

Making IT work – first computer restoration conference

The first-ever international conference of computer conservationists was held in May across two UK venues that have led the world in the developing discipline.

The two-day conference was organised by The National Museum of Computing (TNMOC) and the Computer Conservation Society (CCS). With more than 50 participants from New York, California, Seattle, Paderborn in Germany and across Britain, the growing art and science of computing conservation was discussed and demonstrated, showing the growing maturity of the discipline.

The first day, at the London headquarters of the BCS, focused mainly on the principles of computer conservation. Robert Garner of the Computer History Museum in the US described the restoration and exhibition of a 1960s IBM mainframe computer.

Day two at TNMOC consisted of workshops on world-renowned practical conservation projects on display, including the Colossus rebuild, the Harwell Dekatron restoration and the EDSAC reconstruction.

For those who could not attend the event, but are fascinated by this relatively young discipline, a full set of papers from the conference will be made available online via the CCS and TNMOC websites during the summer.

Pico launches low-cost network analyser

pico Technology
Vector Network Analyzer
PicoVNA 106 300 kHz – 6 GHz Quad RX
Port 1
Port 2

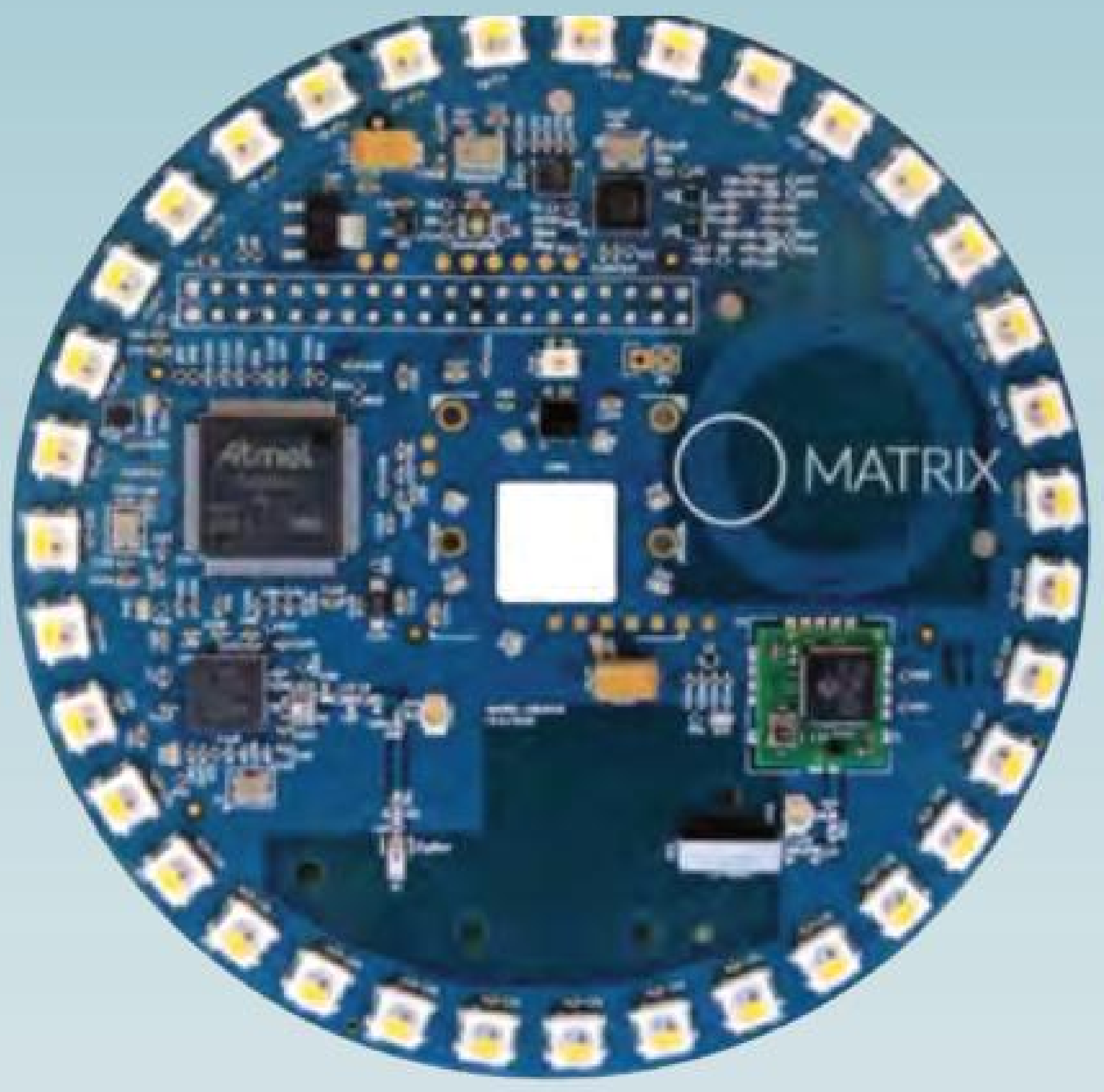
Pico Technology has applied its expertise in compact USB instrumentation, combined with its experience with high-performance sampling oscilloscopes and time domain reflectometry, to launch a high-quality, low-cost vector network analyser.

If you work with high-speed data, communications or computing, you often need to characterise high-frequency interfaces, devices, multipath interconnect and antennas. This product fills a need for a straightforward, accurate, fast, portable and low-cost measurement instrument, one that can support developing applications such as 5G, IoT, radar, and tissue and materials imaging.

The PicoVNA 106 is an all-new, UK-designed, USB-controlled, professional and laboratory-grade 300kHz to 6GHz vector network analyser. It has exceptional dynamic range of up to 118dB at 10Hz and only 0.005 dB RMS trace noise at its maximum bandwidth of 140kHz.

The PicoVNA 106's small size, weight and cost suit it to field service, installation test, embedded and training applications. For more information visit: **www.picotech.com**

More Pi from Farnell



Farnell has announced it is the distributor for MATRIX Creator, a Raspberry Pi add-on that provides multiple functionality and cost-effective development of IoT devices.

MATRIX Creator is particularly suited to home automation systems involving optical and sound elements. Its microphone array allows a user to develop DIY Amazon Echo and Alexa-based projects, as well as voice recognition systems. The optical and physical sensors enable development of facial recognition and motion detection for security applications.

The board incorporates an ARM Cortex M3 microcontroller, sensors for motion, temperature, humidity, light, ultraviolet and infrared, an 8-microphone array and a 35-LED array. It can be programmed in 40 different languages, and incorporates integrated Z-Wave and zigbee communications plus connectivity via a wide range of analogue and digital input/output interfaces. Further details at: **http://bit.ly/2rJziyq**

Eptsoft addresses STEM skills shortages

Digital publisher **eptsoft.com** has launched material to address the problem of key employment skills shortages, especially among young workers in STEM subjects: science, technology, engineering and maths. The company's online course in electronics provides a certificate of completion at the end to bolster CVs.

All eptsoft courses are comprehensive and aimed at both the beginner (some basic level understanding of electronics is assumed) and more advanced students looking for a refresher. Menu driven, the material is interactive and encourages exploration and experimentation.

In addition to the online course content, eptsoft is giving a free PC-based app 'Electronics, Mechanics, Maths & Computing ' (worth around £120 and available on Amazon). For further details, see: **www.eptsoft.com**

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TechnoTalk

Weirdness

Mark Nelson

If 'I'm Sorry, I Haven't a Clue'* is 'the antidote to panel games', then this article must be the antidote to logical electronics. I won't be giving you any 'silly things to do' (the other contributors can look after that – only joking!) but I will share with you some strange aspects of electronics that I have come across recently.

SO MUCH OF THE APPEAL OF practical electronics as a hobby is its predictability. With gardening, tropical fish keeping or even radio-controlled model aircraft there's a significant factor of unpredictability. You invest your hard-earned cash on exotic seeds, rare breeds of fish or some high-performance aeroplane and instead of giving you intense pleasure and pride, the plants are attacked by mildew, the fish catch a mystery disease and your aircraft crashes to the ground for no reason whatsoever. Contrast this with electronics: you pick a project, buy a PCB, solder the components and achieve sublime satisfaction – provided you install all the parts correctly.

That's because electronics obeys rules rigidly. Turn the pot clockwise and the volume increases. Apply a potential difference and the LED illuminates, unless you installed it back-to-front and then it generates negative light, invisible to humans. But for perverse people like me, this assured regularity is rather boring; we need irregularity to sharpen our senses. So let's seek out some weirdness, starting with an electronic project that worked perfectly in the constructor's workshop but didn't when he took it into work to show his colleagues.

Magnificent MSF machine

If you own a radio-controlled wall clock you are probably familiar with MSF, which is the callsign of the British radio timecode transmitter. This serves as our national time reference and is highly accurate, sending out a time signal derived from three atomic clocks. It is also referenced to standards that are maintained by the UK's National Physical Laboratory in Teddington (Middlesex), where the bread delivery man, nicknamed Two Ton Ted, used to live. These days, the MSF transmitter is located in Anthorn (Cumbria) but between 1950 and 2007 it radiated from Rugby, which is why it is still often called the 'Rugby Clock'.

Back in the mists of time another electronics magazine (I believe it had the words 'world' and 'wireless' in its name, although not necessarily in that order) had an extremely complex project to make an MSF time decoder using discrete components. An electronicist I know, who lived in Rugby, decided this would be an ideal challenge for his construction abilities. What's more, he managed to build it and get it to function impeccably. To his acute embarrassment, however, when he demonstrated it to his work colleagues in Coventry, his electronic masterpiece did precisely nothing. Embarrassing is not the word! Of course, it worked perfectly again back at home. After much cursing and debugging, he managed to track down the fault. Can you guess the explanation for this wilful misbehaviour before reading the solution at the end of this article?

Optical fibres in your garden

Nothing to do with super-fast broadband, but something far more natural – scientists at Seoul National University in South Korea have discovered that some plants contain light pipes analogous to optical fibres. Ian Baldwin, a member of the research team, explained: 'Our work proves that roots are able to perceive light, even though they are usually found below ground. Photoreception in the roots triggers a signalling chain that influences plant growth, especially the root architecture.' *New Scientist* magazine stated that the team found that stems of plants act like a fibre-optic cable, conducting light down to light receptors in the roots. These in turn stimulate the production of a protein called HY5, which promotes healthy root growth. But why would they use light? Because sending information using light is a lot faster than chemical transmission. No commercial applications of this phenomenon are proposed, but it is rather fascinating.

Botheration defied

When you're deeply involved in designing or constructing an electronic project, do you resent being disturbed by someone telling you it's coffee time or asking some trivial question that destroys your concentration? I know I do.

One solution would be a traffic light installed on your bench or desk that lights up red when you are not to be disturbed (unless the building is on fire) and green when you are amenable to a chat. A computer scientist at the University of British Columbia has invented a unique desk light that automatically switches from green to red when you are 'in the zone' and shouldn't be disturbed by colleagues. FlowLight is its name, and while it may not sound like an advanced electronics device, in fact it is, because it switches between green and red based on your keyboard and mouse activity. Inventor Thomas Fritz says that it is important for the light to change automatically, because once someone is focused on a task, actively discouraging disturbance is – of course – itself disruptive to the work. 'When you're interrupted, it can take a long time to get back into your work and it's more likely you'll make mistakes,' he says.

Greater respect

Tests using the light by nearly 500 office workers showed that they not only reported fewer interruptions but also felt the office culture was improved, with people more respectful of each other's time and aware of when they could interrupt a colleague. What about electronic assembly work at a bench though? After all, keyboard and mouse activity are not the only indications that someone is hard at work. More is progress on a more advanced version of FlowLight to determine whether it can be improved by using biometric sensors to detect heart rate variability, pupil dilation, eye blinks or even brainwave activity. Amazing or what?

Mischievous MSF: the solution

The problem lay in the very first component in the signal chain. The RF amplifier transistor in the receiver circuitry had been wired back to front. Under normal conditions this blocked reception entirely, but when the circuit operated in the shadow of a transmitter radiating 60kW of power, the mis-wiring had no effect whatsoever!

*Are you clueless?

For (perhaps) younger readers, but especially foreign readers, the reference to 'I'm Sorry, I Haven't a Clue' might have been a bit of a head scratcher. It's the name of a deliberately silly, very long-running BBC radio comedy panel game (**http://www.isihac.net**). It famously includes a game called 'Mornington Crescent' that is intentionally incomprehensible (**http://bit.ly/1SWsSBm**).

Touch-Screen Boat Computer with GPS

12
knots
N
E
S
W
352°

Would you like an accurate digital speedometer for your boat? One with a large clear display? This low-cost unit with touch control is just the shot. It can also display a raft of other information, including your heading, location and the relative bearing to a point of interest, which can be anything from the harbour entrance to a great fishing spot.

AS WITH THE *Garage Parking Assistant* described in June's issue, this project is based on the *Micromite LCD BackPack*. However, for this project, we've deleted the ultrasonic sensor and substituted a low-cost GPS module. By adding a suitable BASIC program, it now functions as a *Boat Computer* that will display your speed as well as a selection of other data on its colourful LCD panel.

Most *EPE* readers will be familiar with the *Micromite LCD BackPack* which was featured in the May 2017 issue. It combines a low-cost, touch-sensitive colour LCD panel with the Micromite, a cheap but powerful microcontroller programmed in the BASIC language. It uses less than a dozen components and can be built in under half an hour.

The only extra component required for our *Touch-Screen Boat Computer* is a GPS module and these are now very cheap – as low as £5 or even less. The 'special sauce' which makes these two parts work together as a boat computer is the BASIC program that takes the data from the GPS module and formats it for display on the LCD.

As emphasised in the original *Micromite BackPack* article, the advantage of BASIC is that it is easy to understand and it is written in plain text. So if you do not like how the program works, you can jump in and change it to suit your own needs.

Even if you have no intention of building the *Touch-Screen Boat Computer*, you might find some of the BASIC program useful for other projects. For example, the keypad routines can be used in many other applications and you are welcome to copy this part of the program (or any other part) for your own designs.

Information display

Because the *Boat Computer* makes extensive use of its graphical display for setting the various options, its operation is intuitive. On power-up, the display is divided into two 'panels'. The top half of the screen shows your speed while the lower half can be used to display a selection of other

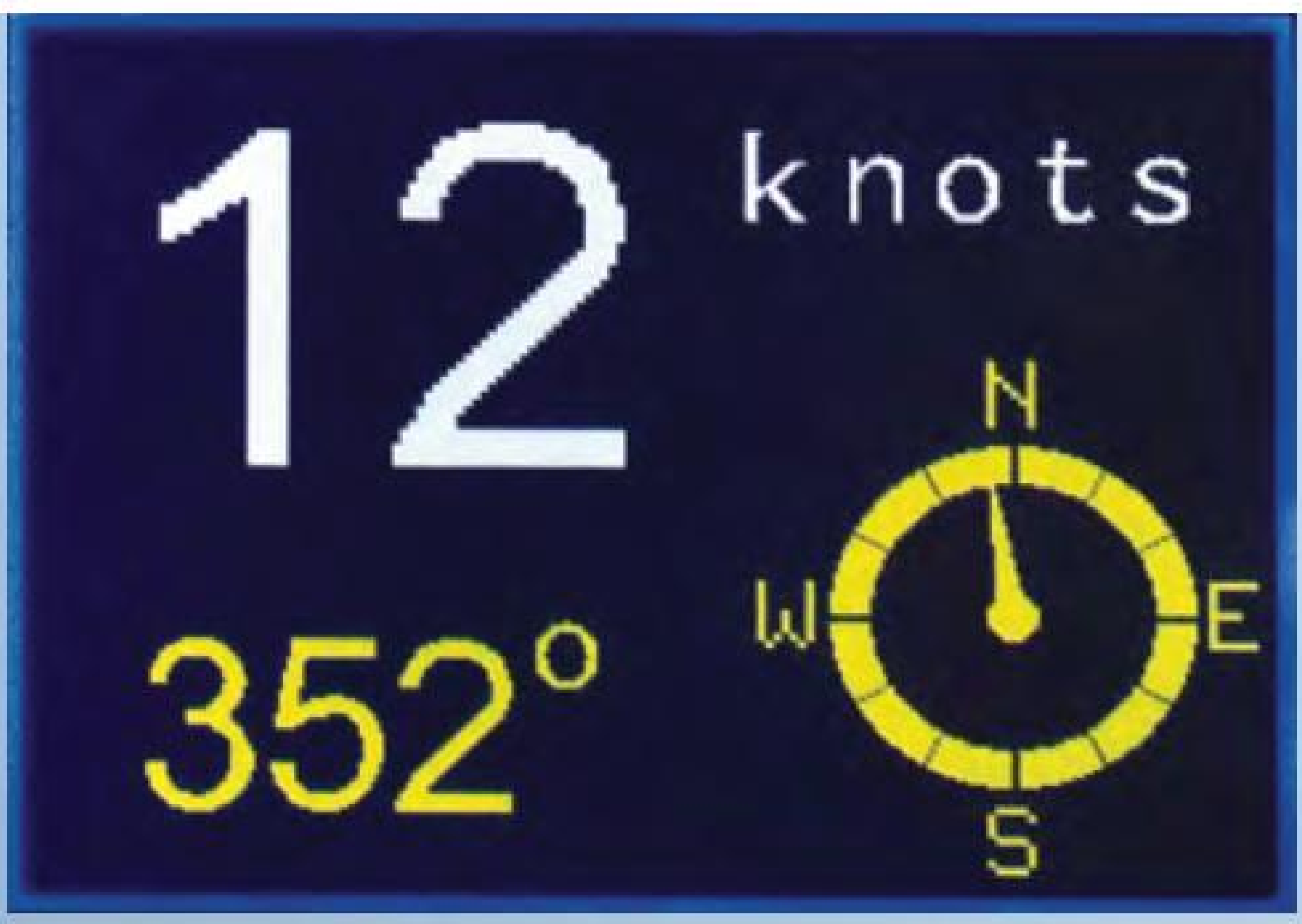


Fig.1: this is the main display shown on the *Boat Computer* when it first powers up. The top half of the screen shows the speed in knots, while the bottom half shows the current heading. The data in both halves can be configured by touching either the top or bottom half of the screen.

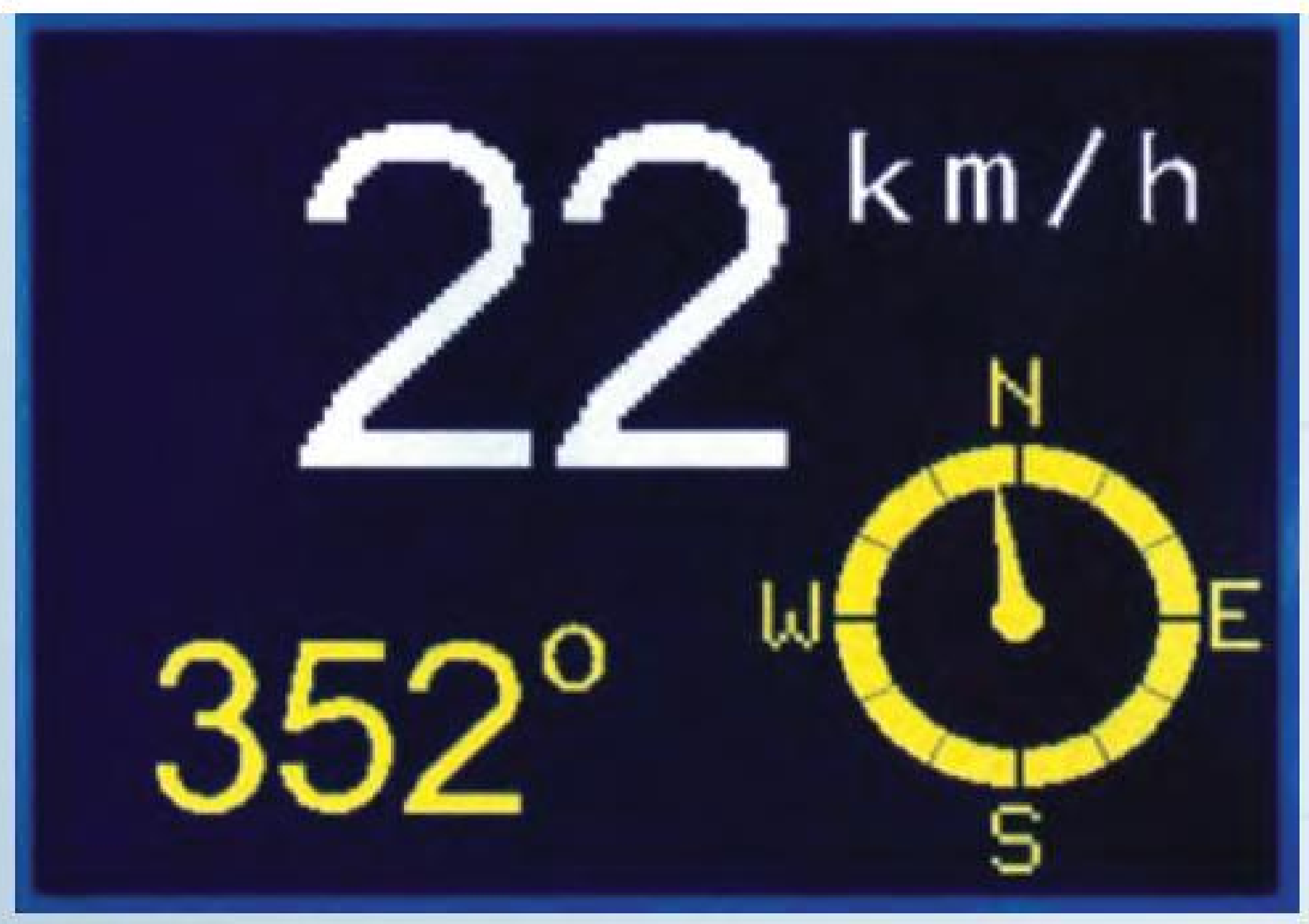


Fig.2: touching the top half of the screen shown in Fig.1 switches the speed indication from knots to km/h.

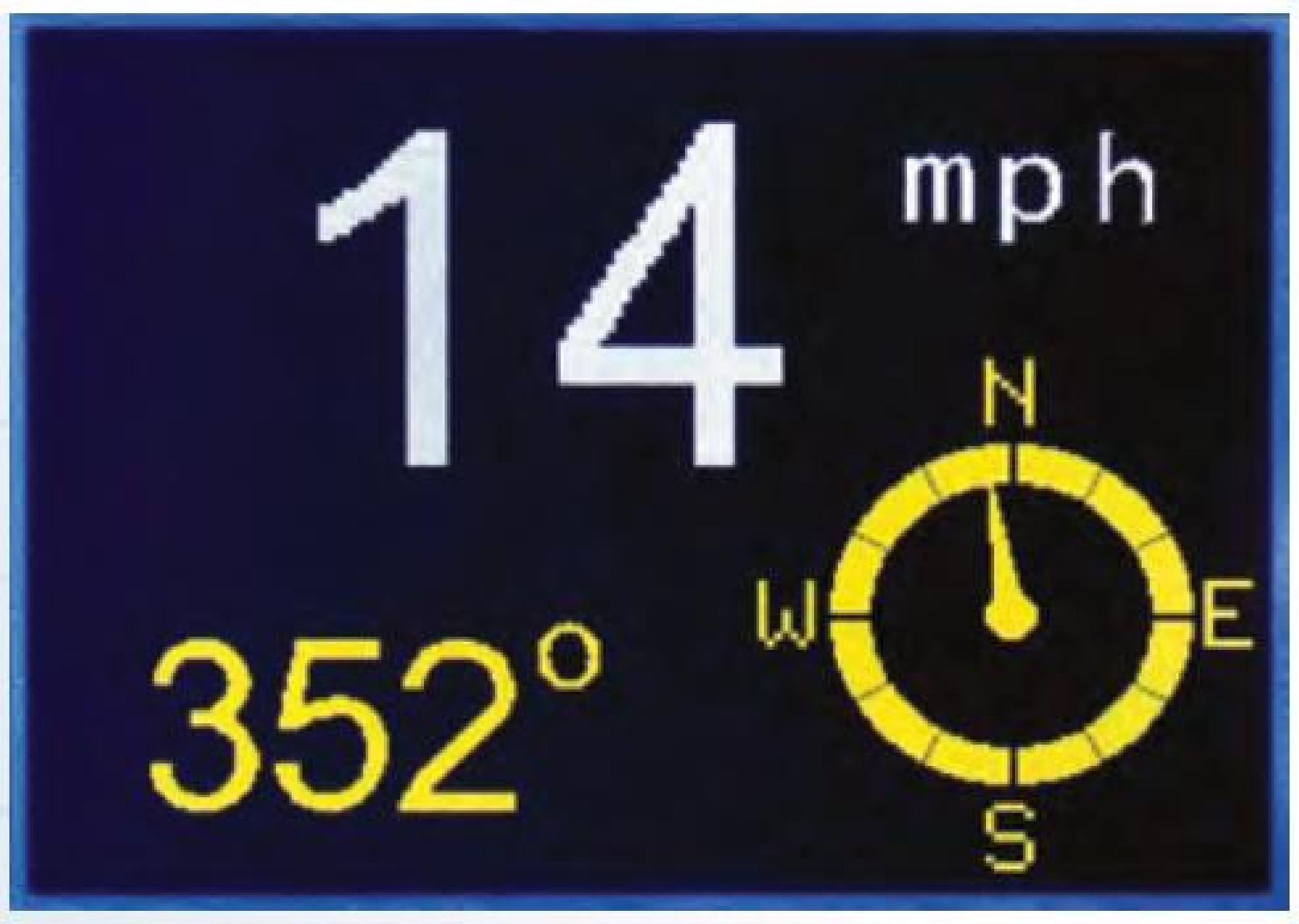
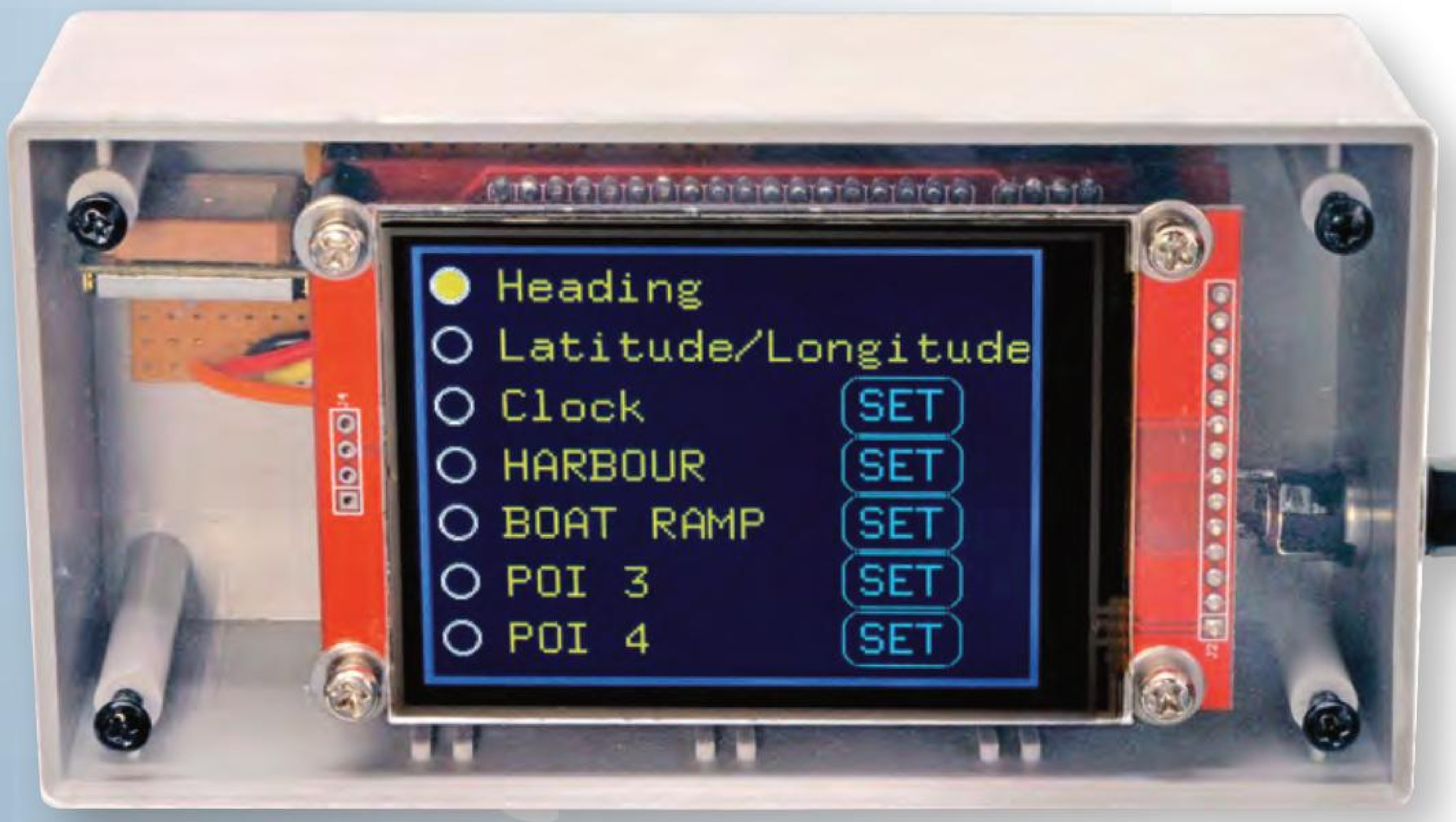


Fig.3: touching the top of the screen again displays the speed in mph. Another touch brings it back to knots.



This photo shows the list of data that can be shown in the lower half of the main display. Touching any option switches the unit back to the main display, with the relevant data displayed in the lower half of the screen. Touching a SET button allows you to configure a particular entry (ie, to set the clock or configure a point of interest (POI).

By Geoff Graham

information, including the current heading, latitude/longitude, time and more. The photo on the facing page shows a typical display.

When the top half of the screen (showing the speed) is touched, the speed display will switch from knots to km/h. A second touch will then change the reading to mph, while touching it again brings the reading back to knots. The selection will be remembered (as will any other changes that are made), even if the power is removed.

Conversely, when the bottom half of the screen is touched, a listing of all the possible display modes will be shown (see above photo). Touching an item in this list will select it and the *Touch-Screen Boat Computer* will then revert to the main display, with the newly selected data shown below the speed.

Some entries have a SET button alongside them. When touched, this will allow you to customise the settings associated with that particular display. All settings are saved in non-volatile memory and will be reinstated on power up.

The various items that appear in the list when the bottom half of the screen is touched are as follows:

Heading: this show's the boat's current heading in degrees and as a compass rose with a pointer. The GPS module uses forward movement to calculate the heading, so the boat needs to be moving for this display to work.

Latitude/longitude: this will display the current latitude and longitude in degrees, minutes and seconds.

Clock: this will show the time accurate to within a second. The SET button allows you to change the time zone, the format (12 or 24-hour) and to enable daylight saving compensation (one hour is added when this is on).

POI 1 to POI 4: four different points of interest (POI) can be saved in the *Touch-Screen Boat Computer*. When one of these is selected, the bottom half of the main display will show the distance to the POI and the relative bearing as a pointer.

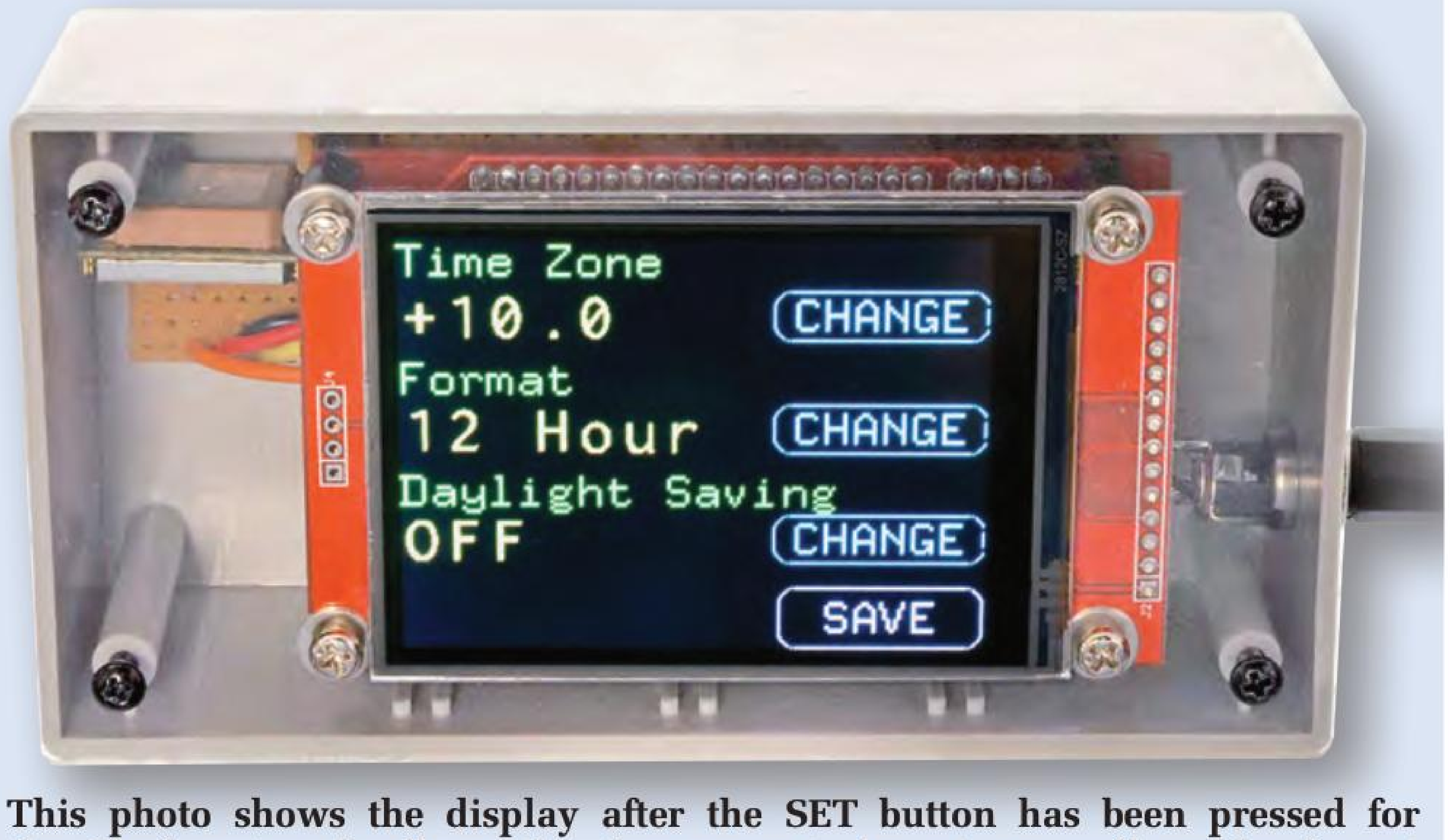
The POI can be anything that you might want to navigate to; eg, a harbour entrance, a boat ramp or a good fishing spot. To navigate to the POI, all you need do is follow the pointer and watch the distance as it counts down to zero.

Each POI entry has a SET button that allows you to set the name for the POI (using an alphanumeric keyboard) and its latitude and longitude. You can also set the POI to your current location – which is handy if you have found a good fishing spot and may want to return.

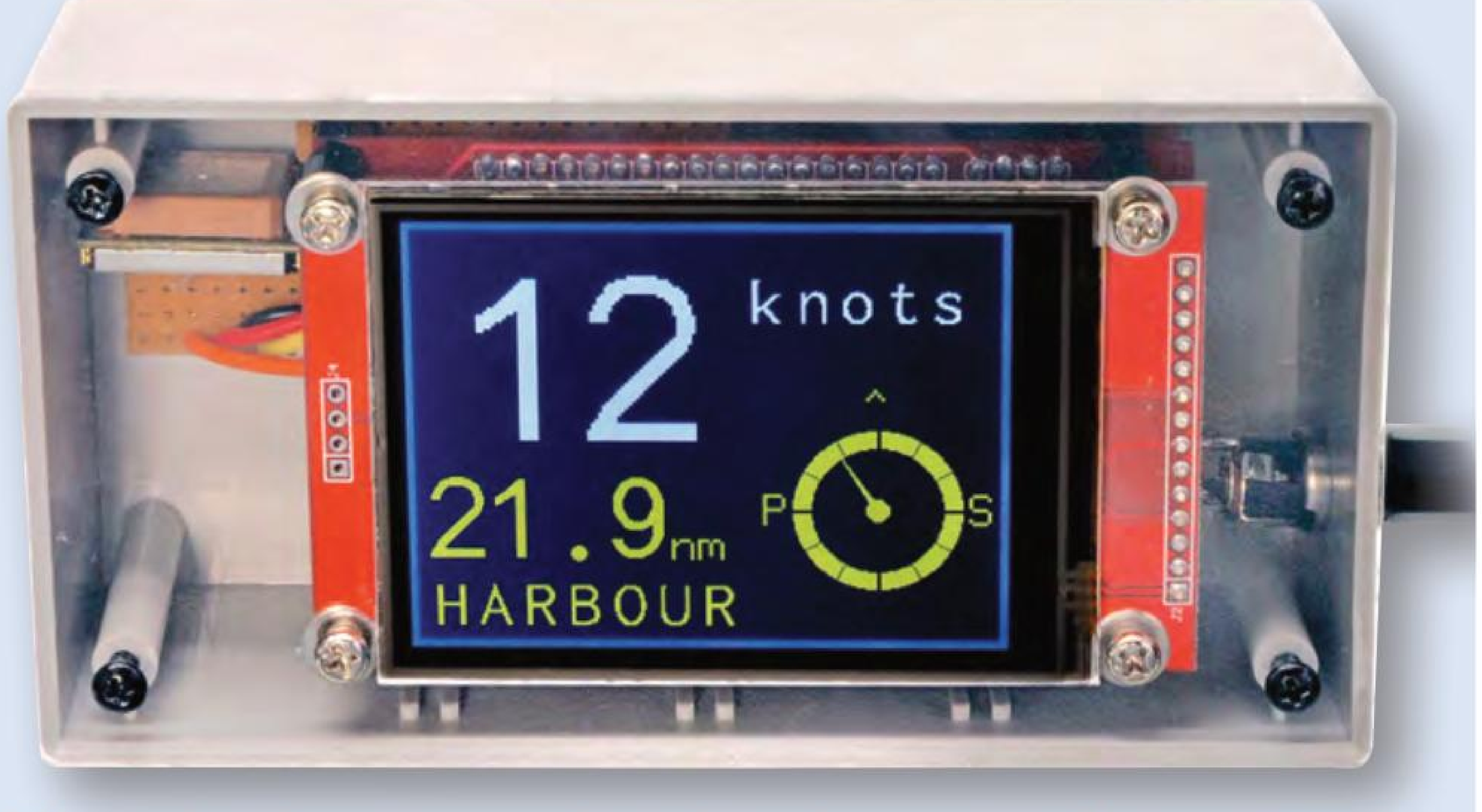
Demonstration mode

There might be occasions when you would like to use the *Touch-Screen Boat Computer* without a GPS module or without a lock on sufficient satellites to get a display. For example, you might wish to explore the menu system without a working GPS module.

To enable this, you can put the unit into demonstration mode and **that's done by touching the centre of the screen while the power is applied.** The LCD will then display 'Demo Mode' as the unit powers up. The device will



This photo shows the display after the SET button has been pressed for the Clock entry. It allows the time zone to be set, as well as the format for displaying the time (12 or 24-hour). It also allows you to select for daylight saving, in which case one hour is added to the displayed time.



This is what the main screen looks like when a point of interest (POI) has been selected for the lower half. It shows the distance and the direction to the selected POI, in this case one named HARBOUR. To navigate to the POI, all you need do is steer in the direction of the pointer and watch the distance as it counts down to zero.

then display an artificial speed, location and time. This data is static (ie, it does not change as you might expect) but it is useful for exploring the menus and features of the *Touch-Screen Boat Computer*.

Because you don't need a GPS module in demo mode, you can try the software on any *Micromite LCD Backpack*, even if you're not planning on building the *Touch-Screen Boat Computer*. Exploring the software may give you ideas for your own projects and you can then extract sections of the BASIC program for your own use.

Selecting a GPS module

It's difficult to specify a particular GPS module for the unit, as manufacturers are constantly discontinuing older models and introducing new versions. To counter this, we have made the unit as flexible as possible, so that it can accommodate almost any GPS module on the market.

Most GPS modules require either a 3.3V or 5V power supply and the *Micromite LCD Backpack* can provide both, so that isn't a problem. Depending on the particular module, the speed of the serial interface can vary from 4800 baud to 38,400 baud. To accommodate this, the BASIC program automatically detects the speed that the module is using (within that range) and sets the interface speed accordingly.

Another variation between modules is that some use TTL-level signalling while others use RS-232. Again, the BASIC program will automatically adjust for whatever standard the module uses. Note, however, that some GPS modules have a USB interface and the *Touch-Screen Boat Computer* cannot work with these.

TTL signalling means that the data will swing from 0V to about 3V, while the output will be at 3V at idle (ie, when there is no signal). RS232 uses the same signalling sequence as TTL, but the voltage swings from –12V to +12V, with idle being –12V (ie, it is inverted with respect to TTL).

GPS modules can also vary in the messages that they send and many of these messages are unique to a particular manufacturer. To avoid this issue, the *Touch-Screen Boat Computer* uses only the RMC message. This message (and its format) is mandatory in the NMEA 0183 standard for GPS hardware, so all GPS modules will produce this signal (the unit will ignore any other messages).

Our prototype used a Fastrax UP501 GPS module (mostly because we had one in our parts box).

More readily available GPS modules include the Ublox NEO-7M-C and NEO-6M, the Skylab MT3329/SKM53, USGlobalSat EM-408 and the V.KEL VK16HX.

In summary, when selecting a GPS module, look for these characteristics: 3.3V or 5V supply rail, 4800 to 38,400 baud rate and a TTL or RS-232 serial interface. In most cases, you will want to choose a module with an inbuilt patch antenna. This takes the form of a flat square ceramic object on the top of the module.

Having an inbuilt antenna makes it simpler to use the module and in most installations, this antenna will gather enough signal to do the job. If the module does not include an antenna, you then have the flexibility of choosing a separate waterproof antenna which could be mounted externally with an unobstructed view of the sky.

Some modules have other peculiarities. For example, the UP501 that we used requires an external 3V battery to keep its memory alive when the power is removed. **Most other GPS modules have this battery incorporated inside them, so this is a rare requirement.**

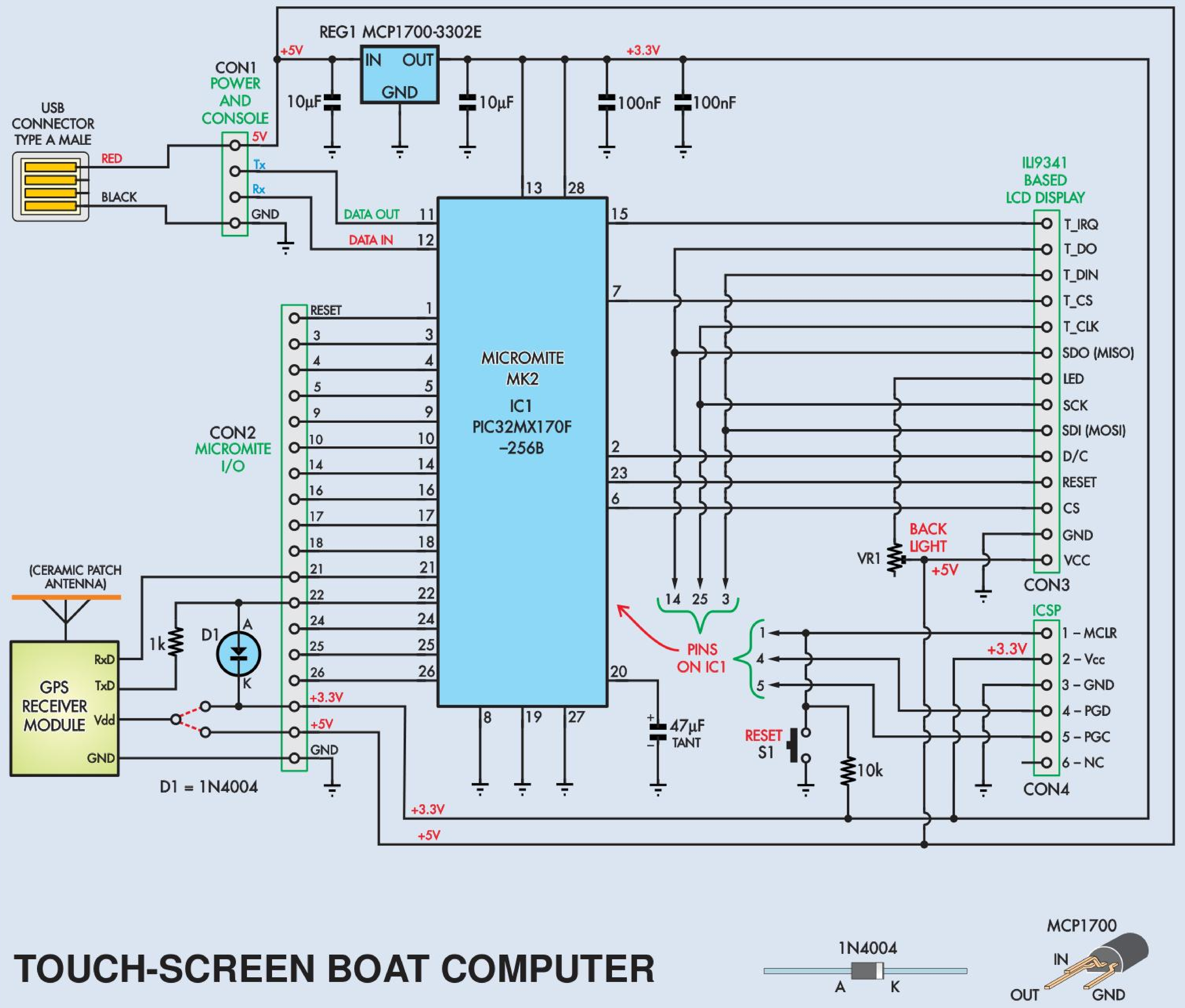
In addition, some GPS modules have an enable input and this must normally be connected to the supply voltage (ie, pulled high). In some cases though, this input should be left floating or even grounded, so check the specifications for your particular module when connecting it to the circuit.

Many modules also feature a 1pps (pulse per second) output but this can be safely ignored.

Circuit details

Fig.1 shows the circuit diagram for the *Touch-Screen Boat Computer*, including the *Micromite LCD BackPack*.

IC1 is the Micromite, which is based on a PIC32MX170F256B microcontroller. It does all the work of taking the data from the GPS module and formatting it for display on the colour LCD which connects to CON3.



REG1 MCP1700-3302E
IN
OUT
GND
+5V
+3.3V
10µF
10µF
100nF
100nF
USB CONNECTOR TYPE A MALE
RED
BLACK
CON1 POWER AND CONSOLE
5V
Tx
Rx
GND
DATA OUT
DATA IN
11
12
13
28
15
7
2
23
6
20
8
19
27
MICROMITE MK2
IC1 PIC32MX170F –256B
CON2 MICROMITE I/O
RESET
3
4
5
9
10
14
16
17
18
21
22
24
25
26
+3.3V
+5V
GND
(CERAMIC PATCH ANTENNA)
GPS RECEIVER MODULE
RxD
TxD
Vdd
GND
1k
D1
A
K
D1 = 1N4004
47µF TANT
ILI9341 BASED LCD DISPLAY
T_IRQ
T_DO
T_DIN
T_CS
T_CLK
SDO (MISO)
LED
SCK
SDI (MOSI)
D/C
RESET
CS
GND
VCC
CON3
VR1
BACK LIGHT
+5V
14 25 3
PINS ON IC1
1
4
5
RESET S1
10k
ICSP
1 – MCLR
2 – Vcc
3 – GND
4 – PGD
5 – PGC
6 – NC
CON4
+3.3V
+5V
TOUCH-SCREEN BOAT COMPUTER
1N4004
A
K
MCP1700
IN
OUT
GND

Fig.1: most of the work in the *Touch-Screen Boat Computer* is done by IC1, which receives data from the GPS module and formats it for a touch-screen colour LCD connected to CON3. Power comes from a 5V DC USB charger and this directly powers the LCD, while 3-pin regulator REG1 provides 3.3V to power IC1. The GPS module is powered by either 5V or 3.3V (depending on the module), while diode D1 and the 1kΩ resistor in series with the GPS module's Tx lead are there to protect IC1 if the GPS module uses RS-232 signalling (rather than TTL).

Power for the circuit comes from a 5V DC USB supply, while low-power voltage regulator REG1 provides a 3.3V rail for IC1. Diode D1 and the 1kΩ resistor in series with the GPS module's transmit (TxD) pin are there to protect IC1 if the module uses RS-232 signalling.

However, if you are sure that your GPS module uses TTL signalling, then D1 can be dispensed with and a link used instead of the 1kΩ resistor.

The circuit has provision for powering the GPS module from either 5V DC or 3.3V DC (from REG1), depending on the module's supply requirements.

Construction

Building the *Touch-Screen Boat Computer* mainly involves building the *Micromite LCD BackPack*, as detailed in the May 2017 issue of *EPE*.

Assembling the *BackPack* PCB is quite simple; just follow the parts layout diagram shown in Fig.2 (as originally published in the May 2017 issue) or the silk screen overlay on the PCB. The 2.8-inch version is the one to build and the job should only take about half an hour.

All GPS modules have a different mounting method, so this is something that you will have to figure out, depending on the module that's being used. **The main consideration when mounting the GPS module is that it should be positioned so that the antenna is horizontal, with its top surface facing the sky, when the *Boat Computer* is being used.** This will ensure maximum sensitivity.

As stated, our prototype used a Fastrax UP501 GPS module and this was mounted on a scrap piece of strip-board. The module was first soldered to a 6-way pin header and this was then plugged into a 6-way female header. This header was then connected via flying leads to an 8-way female header mounted along one edge of the board and positioned so that it could be plugged into CON2 (ie, between pin 21 and GND) on the Micromite. The accompanying photos show the details.

As mentioned above, this particular GPS module also needed a back-up battery for its internal memory and this can also be seen in the accompanying photographs.

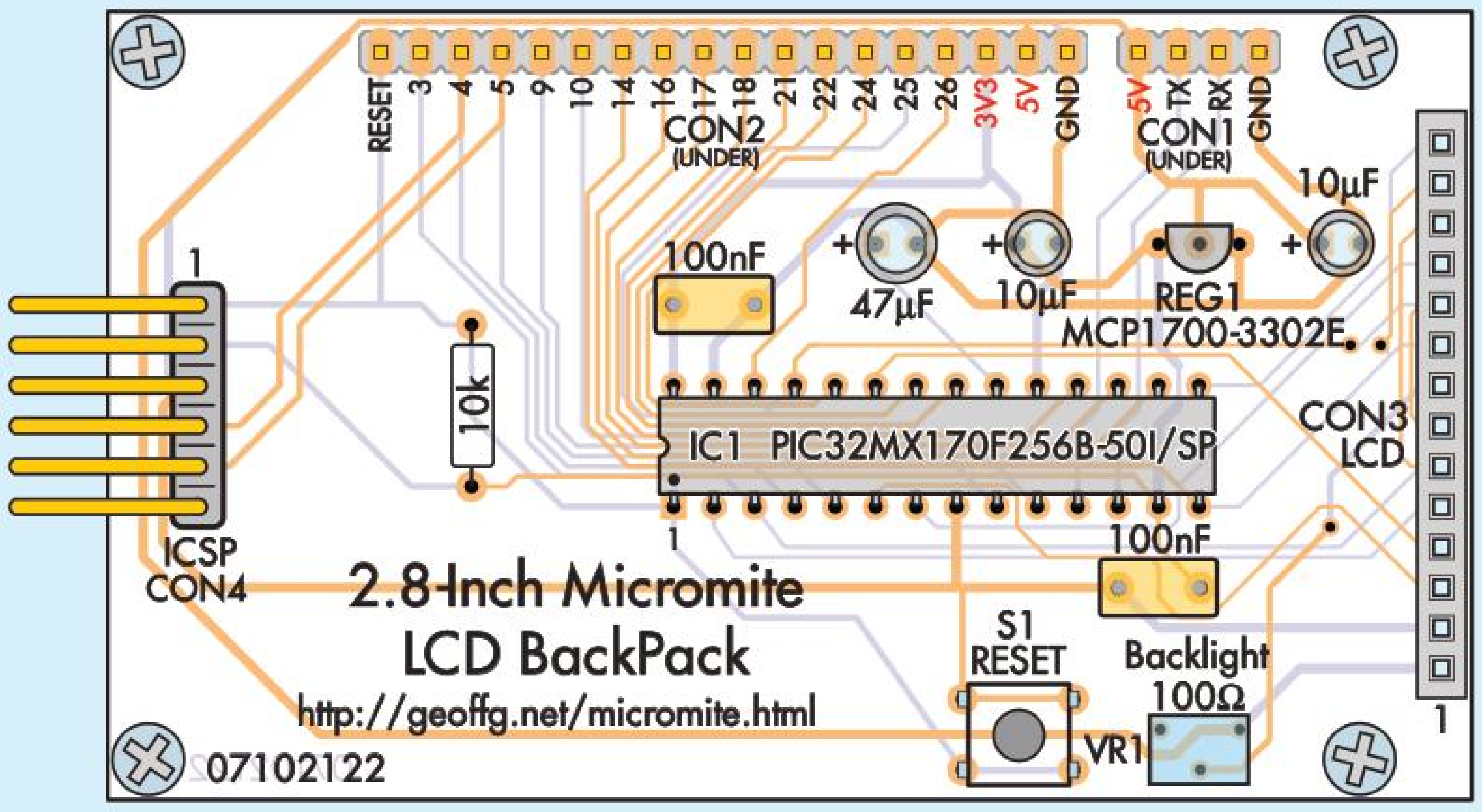
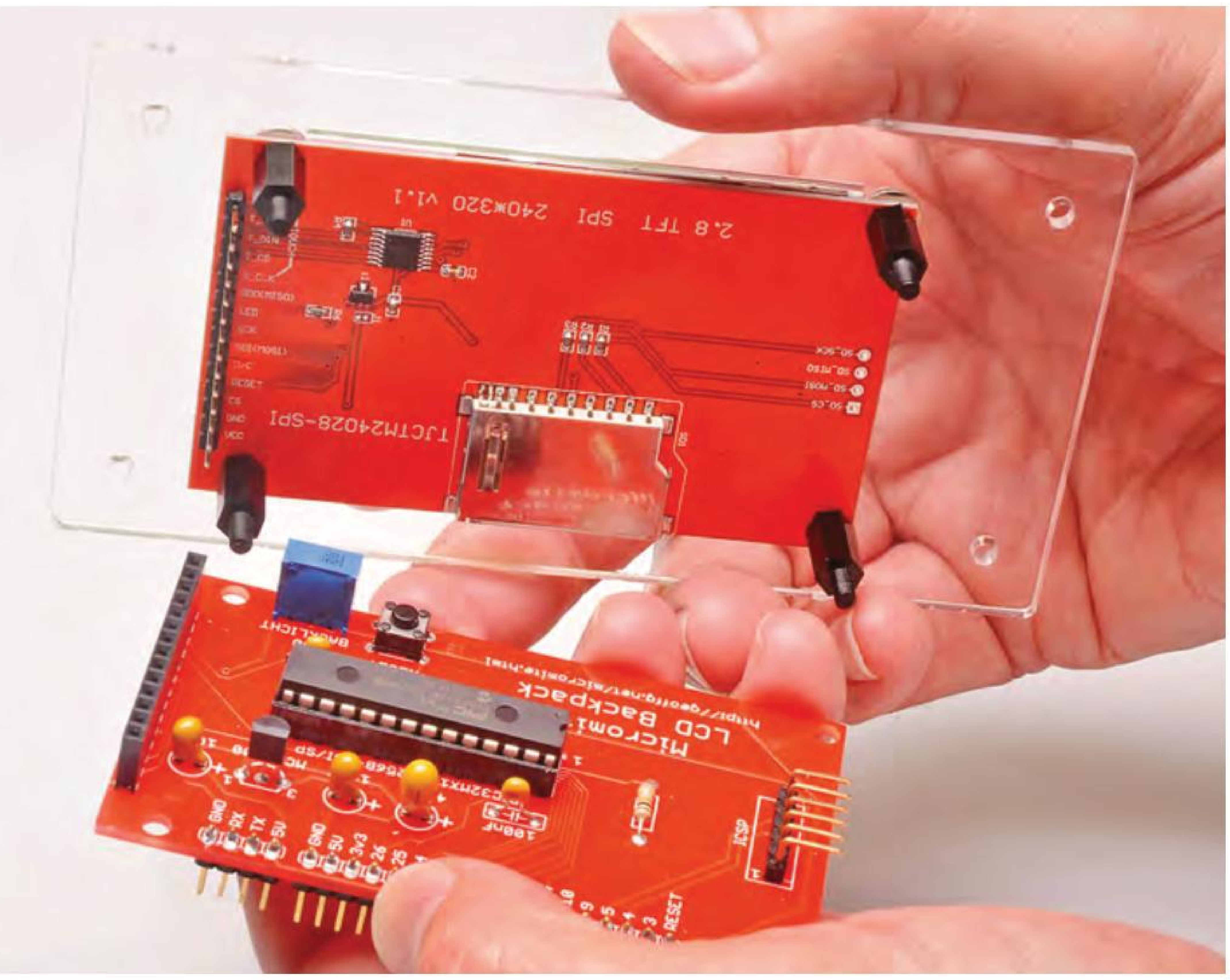


Fig.2: repeated from the May 2017 issue, this parts layout diagram shows how to build the *BackPack* PCB for the 2.8-inch LCD. Note that pin headers CON1 and CON2 are mounted on the rear of the PCB, while CON3 and CON4 are mounted on the top (see photos).



The colour LCD is mounted on the clear acrylic lid before being plugged into the *BackPack* PCB. Be sure to fit the LCD to the lid with the correct orientation.

Loading the firmware

Loading the firmware and the BASIC program is a 4-step process:

Step 1: program the MMBasic firmware into the chip using a PIC32 programmer (eg, a PICkit 3).

Step 2: connect to the Micromite's console and, using the OPTION commands, configure MMBasic for the LCD display and the touch function.

Step 3: load two fonts into the Micromite and save them in the library.

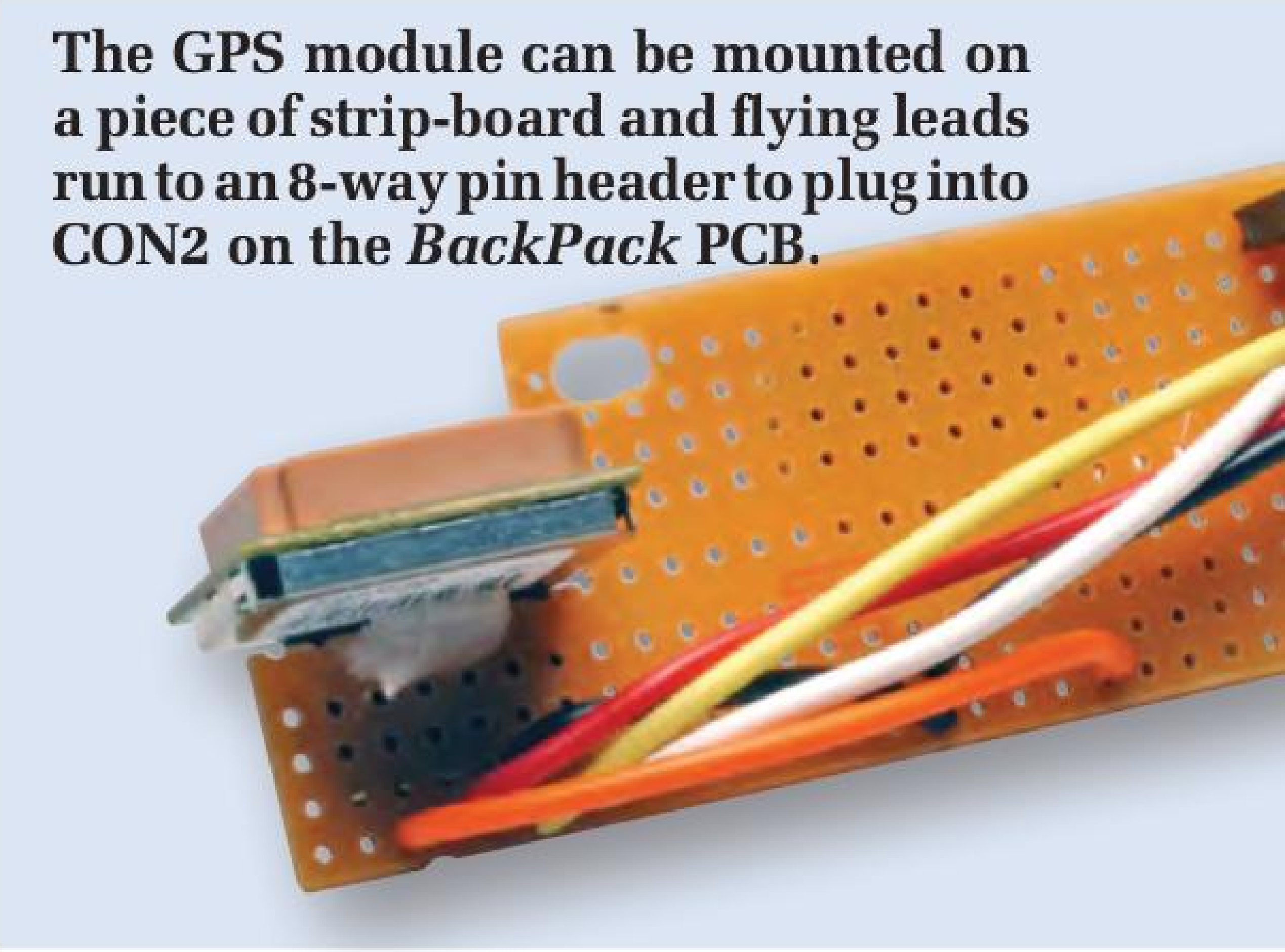
Step 4: last, load the *Boat Computer* program.

Saving the two fonts into the library is something that needs explaining. The library is a special memory area in the Micromite where fonts and program modules can be stored. When these are saved to the library they are, for all intents and purposes, added to the MMBasic language.

They do not show when a program is listed and they are not deleted when a new program is loaded. However, they are available to any program, just the same as the features of MMBasic are always available to any program that is loaded.

One very useful feature of the library is that anything saved into it is compressed. That's why it's necessary to load the two fonts separately from the BASIC program and save them to the library.

The fonts are quite large and there is not enough memory in the Micromite to load both the fonts and the program at the same time. This means that we must first load the fonts and save them to the library, where they will be compressed. We can then load the main program (which relies on the two fonts being available) into main memory.



The GPS module can be mounted on a piece of strip-board and flying leads run to an 8-way pin header to plug into CON2 on the *BackPack* PCB.

As with last month's *Garage Parking Assistant*, you have a few choices when it comes to loading the firmware. You can combine all of the above steps into one by downloading the file **BoatComputerFull.hex** from the *EPE* website and programming it into a blank PIC32 chip using a PICkit 3. This file has the Micromite firmware, the settings for the LCD panel, the two fonts and the BASIC program all combined into one hex file.

Using this method of loading the firmware makes the job easy because the one operation will completely set up the microcontroller to be a boat computer.

Pre-programmed chip

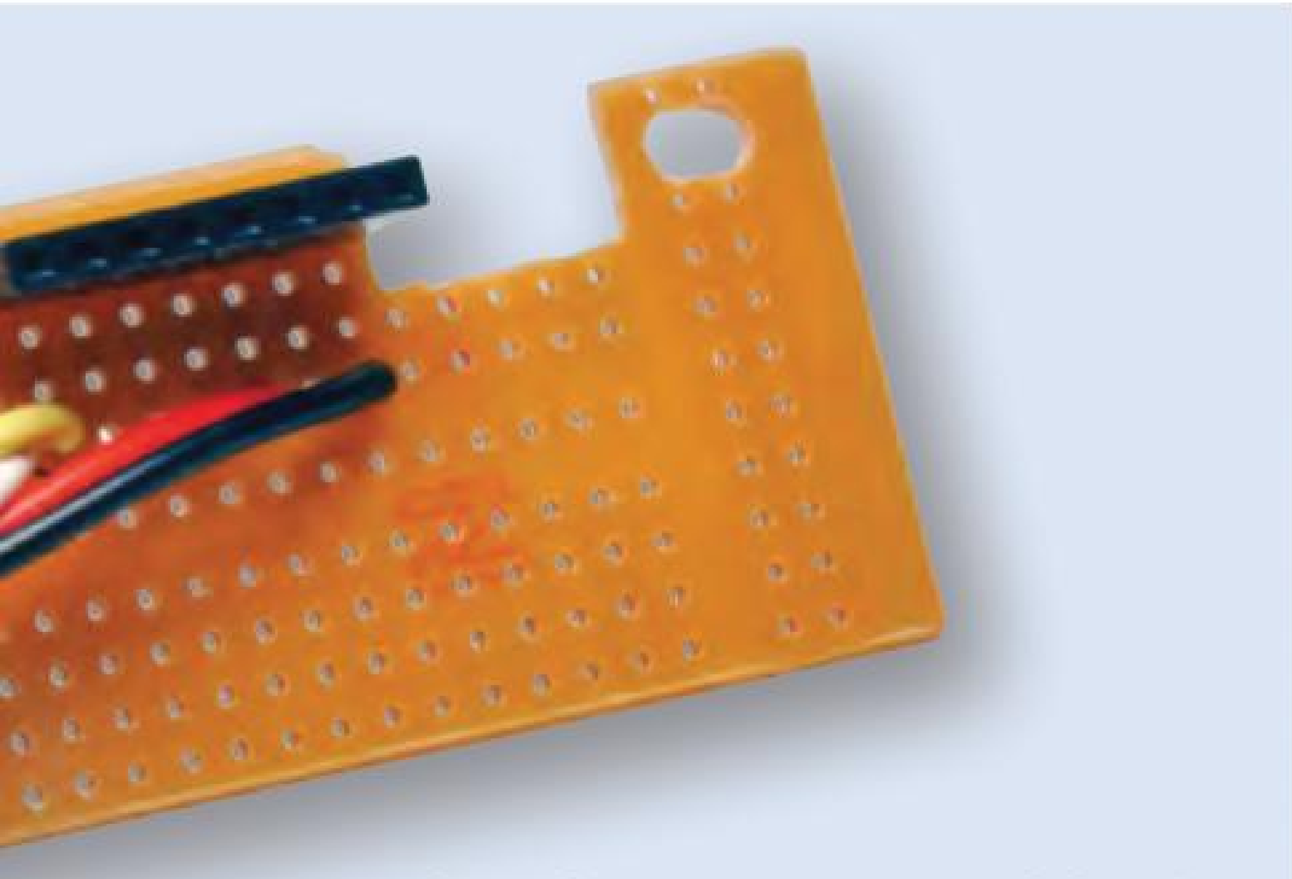
An even easier option is to purchase a pre-programmed PIC32 microcontroller from **micromite.org**. Then, all you have to do is plug the chip into its socket and it will be ready to go (no programming needed).

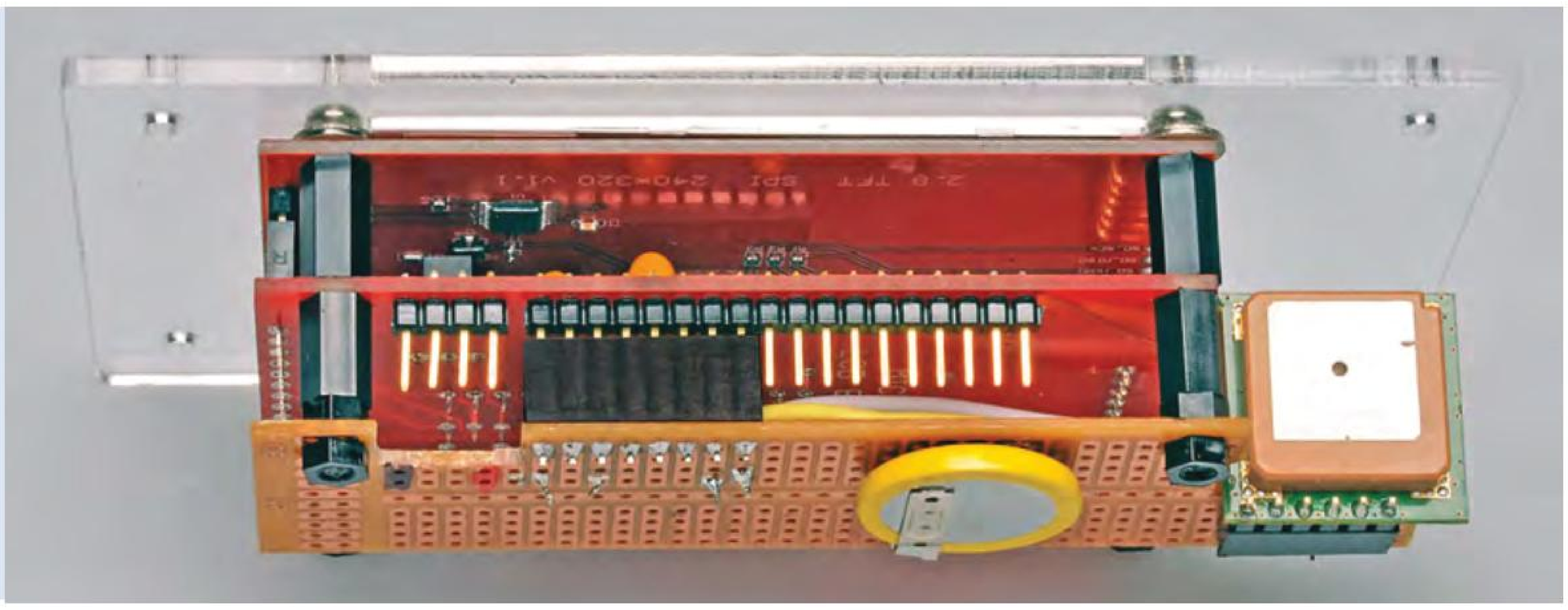
Programming in steps

Yet another option is to go through all four steps individually. First, download the file **Micromite_V5.1.hex** from the author's website (**geoffg.net/micromite.html**) and program it into the PIC32 microcontroller using a PICkit 3. That done, connect a USB-to-serial converter to the console of the Micromite (see panel below) and configure the chip to work with the LCD panel and touch input.

Next, load the file **BoatComputerFonts.bas** into the Micromite using either the XMODEM protocol or the AUTOSAVE command. Once the fonts have loaded, execute the command LIBRARY SAVE. This will save the fonts in the library and remove them from main memory. You can confirm this by running the command MEMORY, which will show that about 12KB of memory has been allocated to the library and there is nothing in the main program memory.

Finally, load the BASIC program **BoatComputer.bas** using either the XMODEM protocol or the AUTOSAVE command. All the files listed above are available from the *EPE* website.





Right: the GPS assembly mounted in position on the *BackPack* PCB.

The process for loading MMBasic, configuring the interpreter and loading BASIC programs was detailed in the article describing the *Micromite LCD BackPack* in the May 2017 issue. It's also explained in the *Micromite User Manual*, which is included in the Micromite firmware zip file.

When you have run through all four steps described above, the result will be exactly the same as if you had programmed a blank chip with the combined file **BoatComputerFull.hex** (or purchased a pre-programmed chip).

Be aware, however, that the touch calibration in the combined firmware file (and in pre-programmed PIC32s) was done with a reasonably standard LCD panel. Most panels require similar parameters for calibrating the touch-sensitive screen but yours might require re-calibration if it is significantly different from the 'standard'.

If you use the combined firmware file and find that the touch calibration is inaccurate, you can correct this by connecting a USB-to-serial converter to the console, halting the program with CTRL-C and re-running the calibration as described in the original *Micromite LCD BackPack* article in May 2017.

Don't worry if you don't have this article. The *Micromite User Manual* (included in the firmware zip file available from the *EPE* website) also contains a full description of the calibration procedure. In fact, you should download the manual in any case, as it fully documents the Micromite and what you can do with it – and that's a lot.

Testing the GPS module

In most cases, you will be able to connect the GPS module to the *Micromite Backpack* and it will just start running without drama. When the *Boat Computer* is first turned on, you will see the message 'Waiting for GPS' on the LCD panel. This means that the BASIC program is searching for the baud rate being used by the module.

If, after 10 seconds you see the message 'GPS Module Not Found' it means that the BASIC program has tried all the possible baud rates and TTL/RS-232 combinations and did not find the module. The software will then keep searching but you obviously need to diagnose the issue.

In most cases, the cause will be incorrect wiring or an enable input to the GPS module that needs to be permanently connected to the supply voltage or to ground (check the specifications for your module). To investigate what is going on, connect the unit to a PC via a USB-to-serial converter, enter the following program into the Micromite via a terminal emulator (eg, Tera Term) and run it:

```
OPEN "COM1:9600" AS #1
DO
  PRINT INPUT$(1, #1);
  T$ = INKEY$
  IF LEN(T$) THEN PRINT #1, T$;
LOOP
```

Replace the 9600 with whatever baud rate you want to use. If you suspect that the module is using RS-232, you should tack `,INV` on the end of the baud rate, eg:

```
OPEN "COM1:9600,INV" AS #1
```

When you run this program, anything that the GPS module outputs will be echoed on the console, so you can see exactly what the unit is receiving. The accompanying panel 'Understanding a GPS module's output' provides further information on the content of the messages that you should be seeing.

Using the above program, you can also send commands to the module. Anything that you type on the console's keyboard will be sent to the module. For example, the following will reset a module using the SIRF chipset to its factory default settings:

```
$PSRF104,00,00,00,00,00,00,12,
08*29
```

All commands sent to the module (including the above) must be terminated with a Ctrl-M character, followed by Ctrl-J (ie, carriage return/line feed). Use Ctrl-C to exit the test program.

Finding satellites

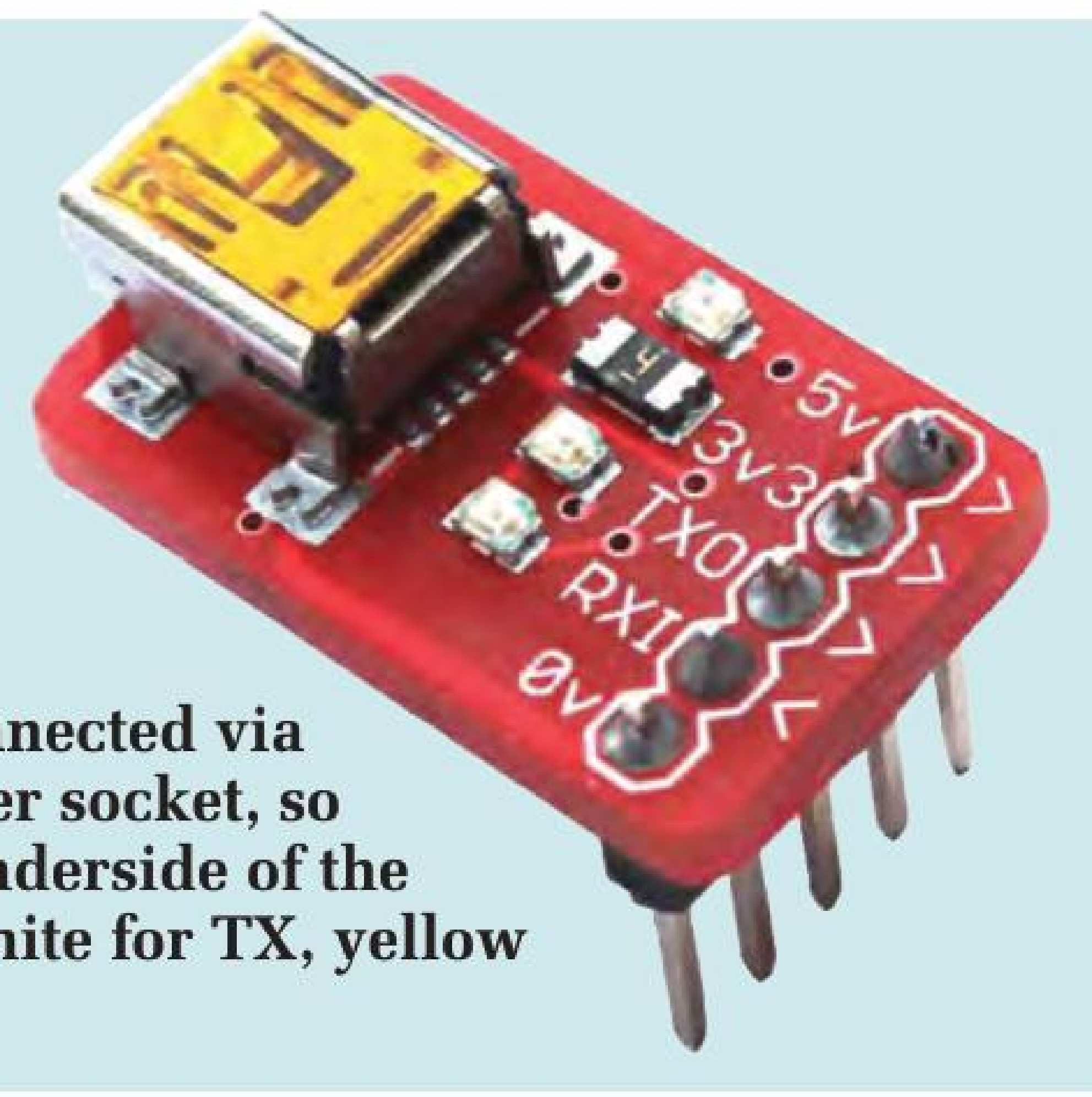
When the *Touch-Screen Boat Computer* receives valid data from the GPS module after power-up, the displayed message changes from 'Waiting For GPS' to 'Searching for Satellites'. This means that the GPS module is working and is scanning for satellites in order to get a fix (this requires at least four satellites).

You could be waiting for a while here so don't panic if nothing happens

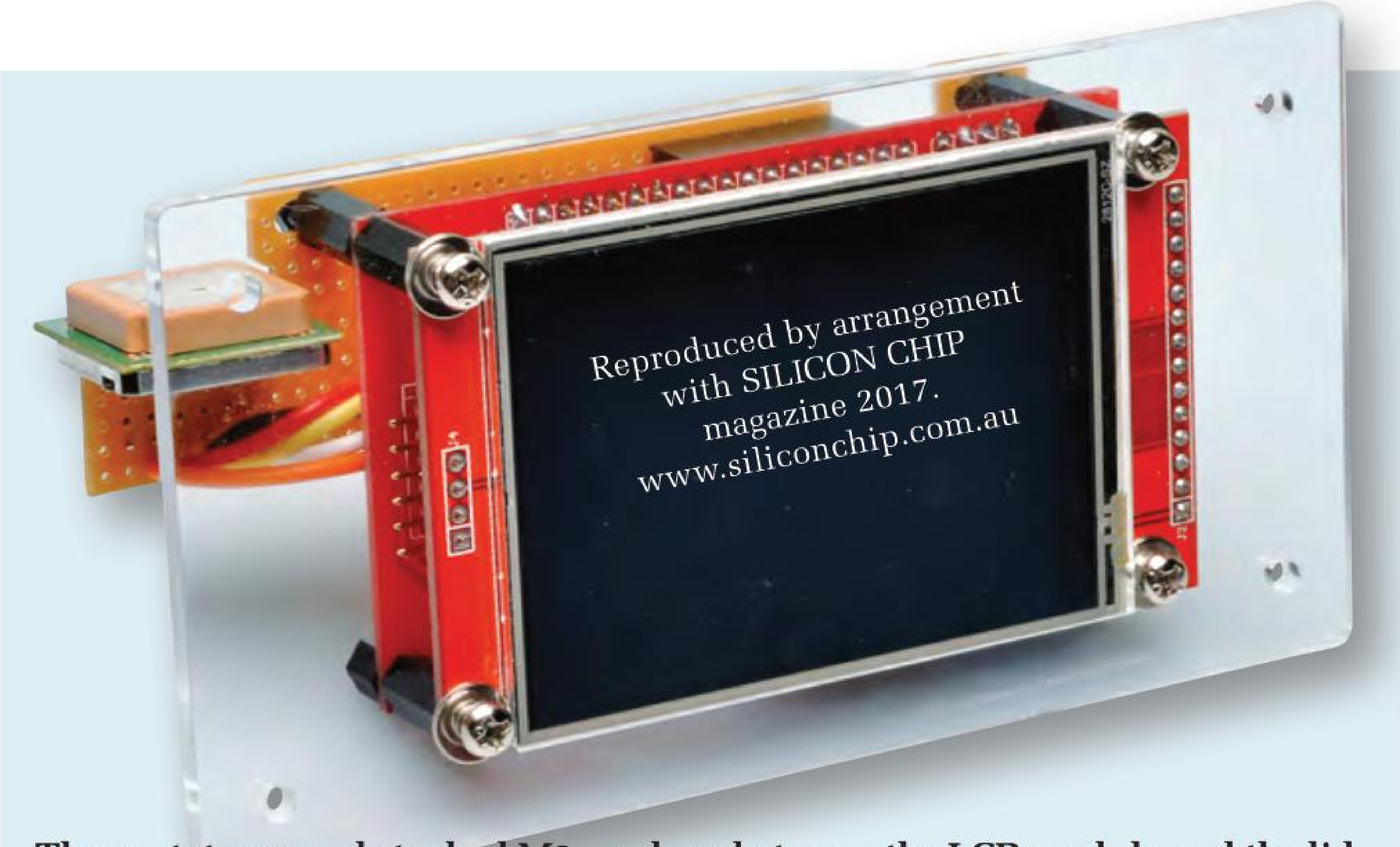
Loading BASIC with a USB-to-serial converter

If you are going to load the BASIC program yourself or edit it later, you will need to make up a cable with a USB-to-serial converter such as this unit from **micromite.org**. This is connected to a PC via mini-USB cable.

After you have the program running to your satisfaction, you can then unplug the converter and use the power cable shown in Fig.4 instead. This is because the program is designed to start running automatically whenever power is applied; after the program has been run once you should never need to use the console again.



The USB-to-serial converter should be connected via colour-coded flying leads to a 4-way header socket, so that it can be plugged into CON1 on the underside of the *BackPack* PCB. Use a red wire for +5V, white for TX, yellow for Rx and black for GND.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The prototype used stacked M3 washers between the LCD module and the lid, but a single spring washer at each corner is a better solution (see text). Be sure to run a thin bead of silicone around the edge of the LCD before fitting it to the lid, to ensure a water-tight seal.

immediately. When a GPS module is first turned on, it must download details of the satellite's orbits which are encoded on the GPS signal. **Receiving the full set of data takes 12.5 minutes and if there is a corruption in the signal, it could take a lot longer.** The answer is to take the whole unit outside with a long power lead, and place it so that it has a clear, uninterrupted view of the sky and give it half an hour or more.

When this data has been received, the module will save it in its battery-backed memory so that, at next power-up, the module finds the satellites much faster (normally within 10-15 seconds). However, this data does change with time, so if you have not used your *Touch-Screen Boat Computer* for some time, it might have to go through the whole process of loading fresh orbital data again (with a corresponding delay).

You will know when the module has found sufficient satellites to locate your position because the 'searching' message will disappear and the display will switch to showing your speed and heading.

Enclosure

Building the unit into an enclosure is left until after the *LCD BackPack* assembly and GPS combination has been thoroughly tested. Once that's done, it can be housed in a UB3 plastic enclosure fitted with a laser-cut clear acrylic lid. (You can make your own or purchase it from the SILICON CHIP Online Shop. It is supplied with all the necessary mounting holes and a precision cut-out for the touch-screen LCD panel.)

An important feature of the enclosure is that, while the LCD touchscreen must be accessible, it must prevent salt spray (or even salt-laden air) from reaching the interior.

The fit between the edges of the LCD and the cut-out in the acrylic lid is very close and this is the secret to spray-proofing the enclosure. Before mounting the LCD panel, the idea is to run a thin bead of transparent silicone sealant around the edge so that when it's mounted on the acrylic panel, the sealant will fill this small gap and render the front spray-proof.

Once the sealant has cured it will be difficult to remove the LCD panel, so make sure that the *Touch-Screen Boat Computer* is working properly and that the LCD panel and the *Micromite BackPack* correctly fit in the box before taking this final step. It may be necessary to trim the row of 14 solder joints on the top of the LCD module, so that they don't interfere with the lid.

Fig.3 shows how it all goes together. The first step is to attach the LCD panel (without the *BackPack* PCB) to the acrylic lid at each corner using an M3 × 10mm machine screw, an M3 spring washer and an M3 × 12mm tapped spacer. The spring washers must be placed between the acrylic lid and the display's PCB so that the LCD panel will be flush with the surface of the lid. **Note that the cut-out in the lid for the LCD is offset to the left so that the active area of the LCD is centred horizontally.**

The easiest way to go about the assembly is as follows:

Step 1: run a very thin bead of silicone around the outside top edge of the LCD.

Step 2: sit the LCD panel on a horizontal surface and carefully place the four spring washers in position. They can each be held in place with tiny blob of silicone.

Step 3: place the lid in position over the LCD and feed the four M3 × 20mm mounting screws through the holes.

Step 4: secure the assembly by screwing on the four M3 × 12mm tapped spacers.

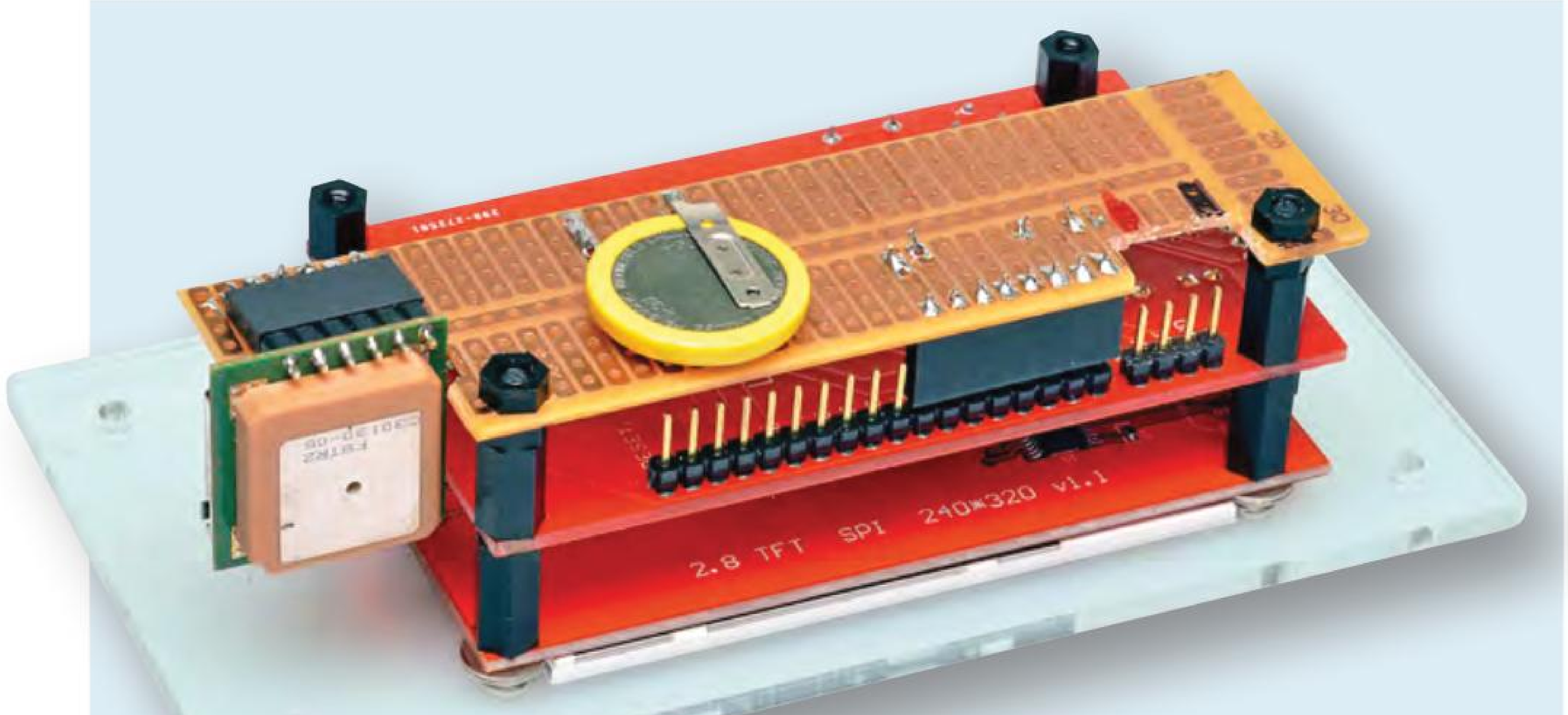
Because of the need to fit the washers, this procedure is a bit fiddly. Take your time and be careful to ensure that you don't get silicone everywhere.

Once the LCD panel has been mounted and sealed, the *Micromite BackPack* PCB can be connected to it via CON3 and secured in place using M3 × 12mm tapped spacers.

As mentioned earlier, the GPS module will need to be mounted separately according to the needs of the module that you are using. This could involve mounting the module on a scrap of strip-board as we did, or perhaps simply attaching it to the top of the case using silicone sealant and running flying leads to a header that plugs into CON2 of the *Micromite Backpack.*

Power supply

The *Touch-Screen Boat Computer* is powered from a 5V USB charger with an output of 500mA or more. Versions



The GPS module used in the prototype required a separate back-up battery and this was also mounted on the strip-board. If you don't need a separate battery, you can simply glue the GPS module to the top of the case and run flying leads to an 8-way pin header to connect to CON2 on the *BackPack* PCB.

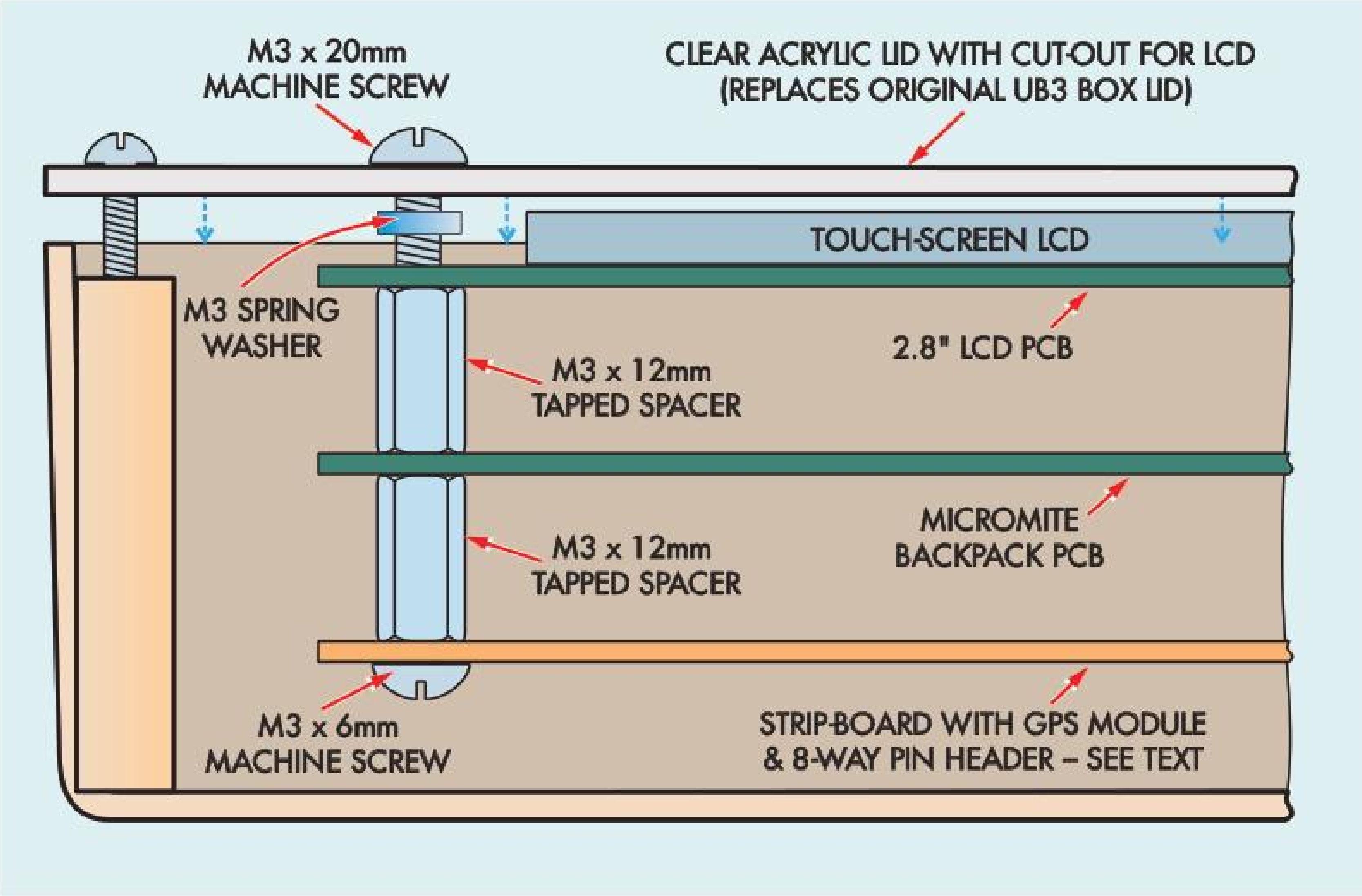
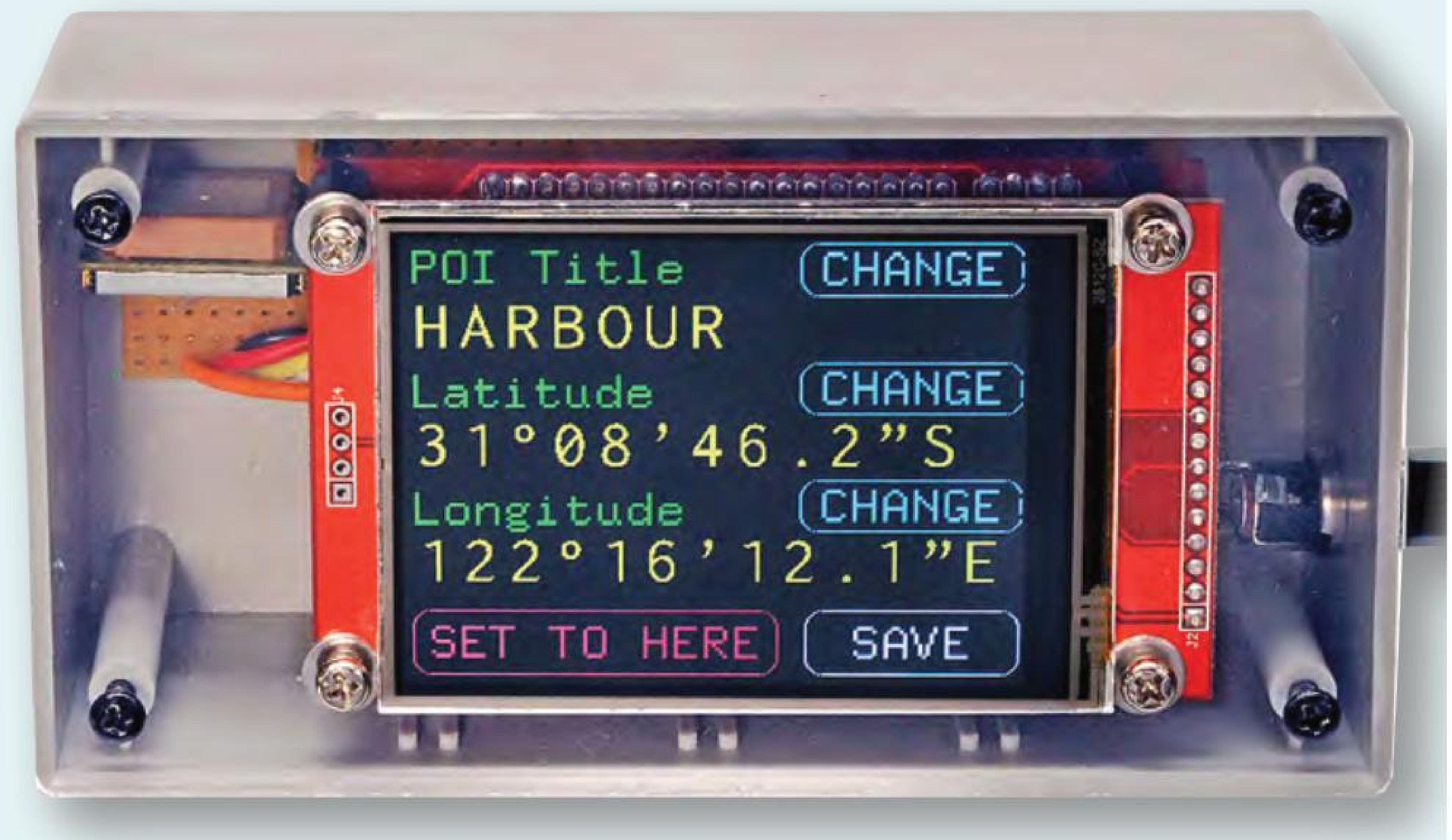

M3 x 20mm MACHINE SCREW
CLEAR ACRYLIC LID WITH CUT-OUT FOR LCD (REPLACES ORIGINAL UB3 BOX LID)
TOUCH-SCREEN LCD
M3 SPRING WASHER
2.8" LCD PCB
M3 x 12mm TAPPED SPACER
MICROMITE BACKPACK PCB
M3 x 12mm TAPPED SPACER
M3 x 6mm MACHINE SCREW
STRIP-BOARD WITH GPS MODULE & 8-WAY PIN HEADER – SEE TEXT

Fig.3: here's how to attach the LCD and *Micromite BackPack* PCB to the clear acrylic lid. The LCD goes through a cut-out in the lid and sits flush with its top surface.

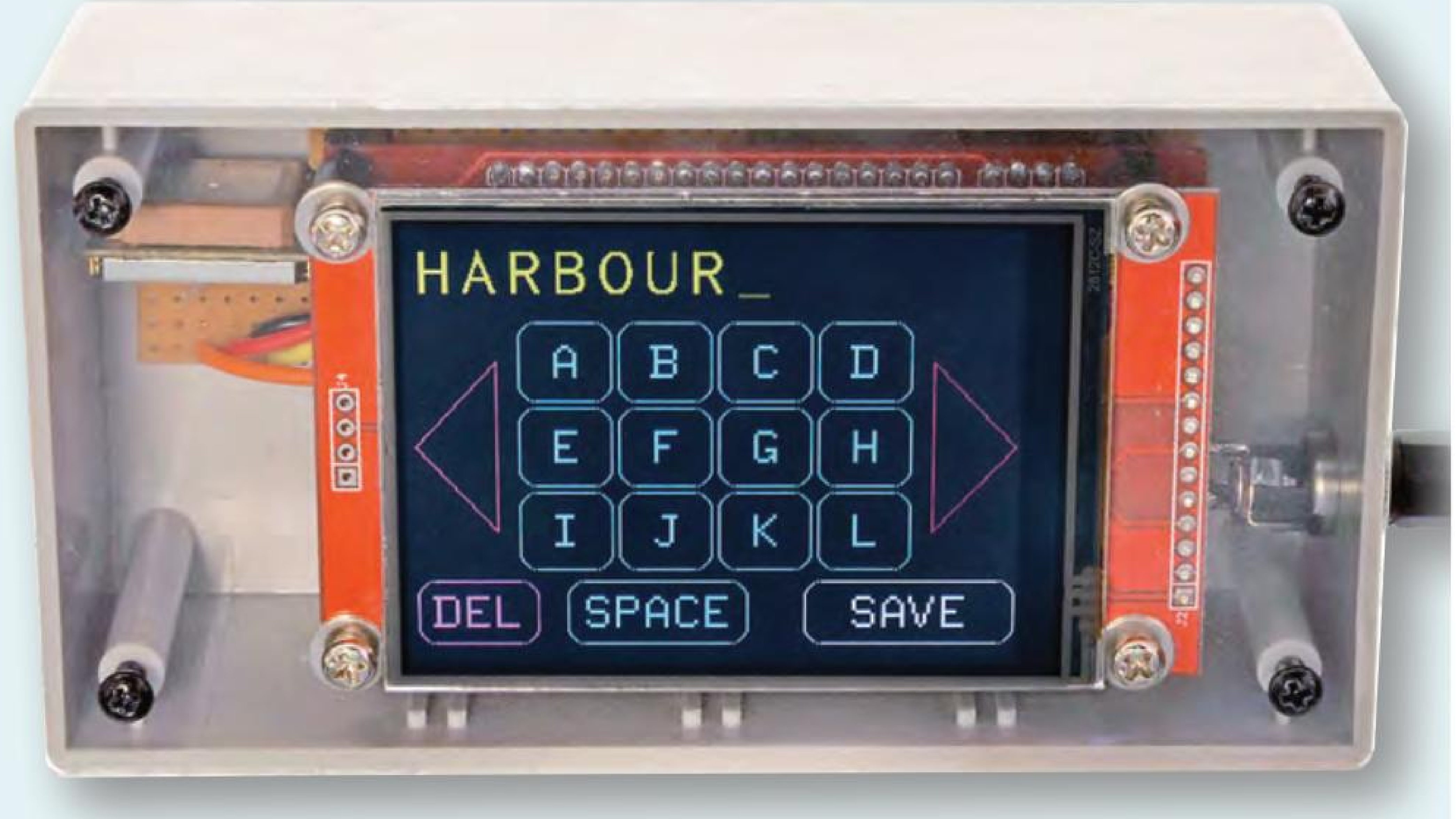
which plug into a 12V cigarette lighter socket are fine in this role.

If you wish to permanently connect the unit to your boat's 12V or 24V wiring you can use one of the many step-down power supply modules available on eBay for just a few dollars (search for 'Buck Converter'). Alternatively, use one of our *USB Charger Regulators* described in the July and December 2016 issues.

To make a cable for a USB charger, cut off one end of a USB cable (retaining the type A male connector on the other end) and thread the cut-off end through a cable gland fitted to one side


POI Title
CHANGE
HARBOUR
Latitude
CHANGE
31°08'46.2"S
Longitude
CHANGE
122°16'12.1"E
SET TO HERE
SAVE

This is the set-up screen for a point of interest (POI). The title of the POI and its latitude and longitude can be changed by touching the CHANGE button beside each entry. A useful feature is the SET TO HERE button, which will set the coordinates to your current location – handy if you have found a good fishing spot.


HARBOUR_
A
B
C
D
E
F
G
H
I
J
K
L
DEL
SPACE
SAVE

This photo shows the display after touching the CHANGE button for a POI title. It allows you to change the title given to a POI. Touching a button will insert that character while touching the red left/right triangles will scroll through the alphabet.

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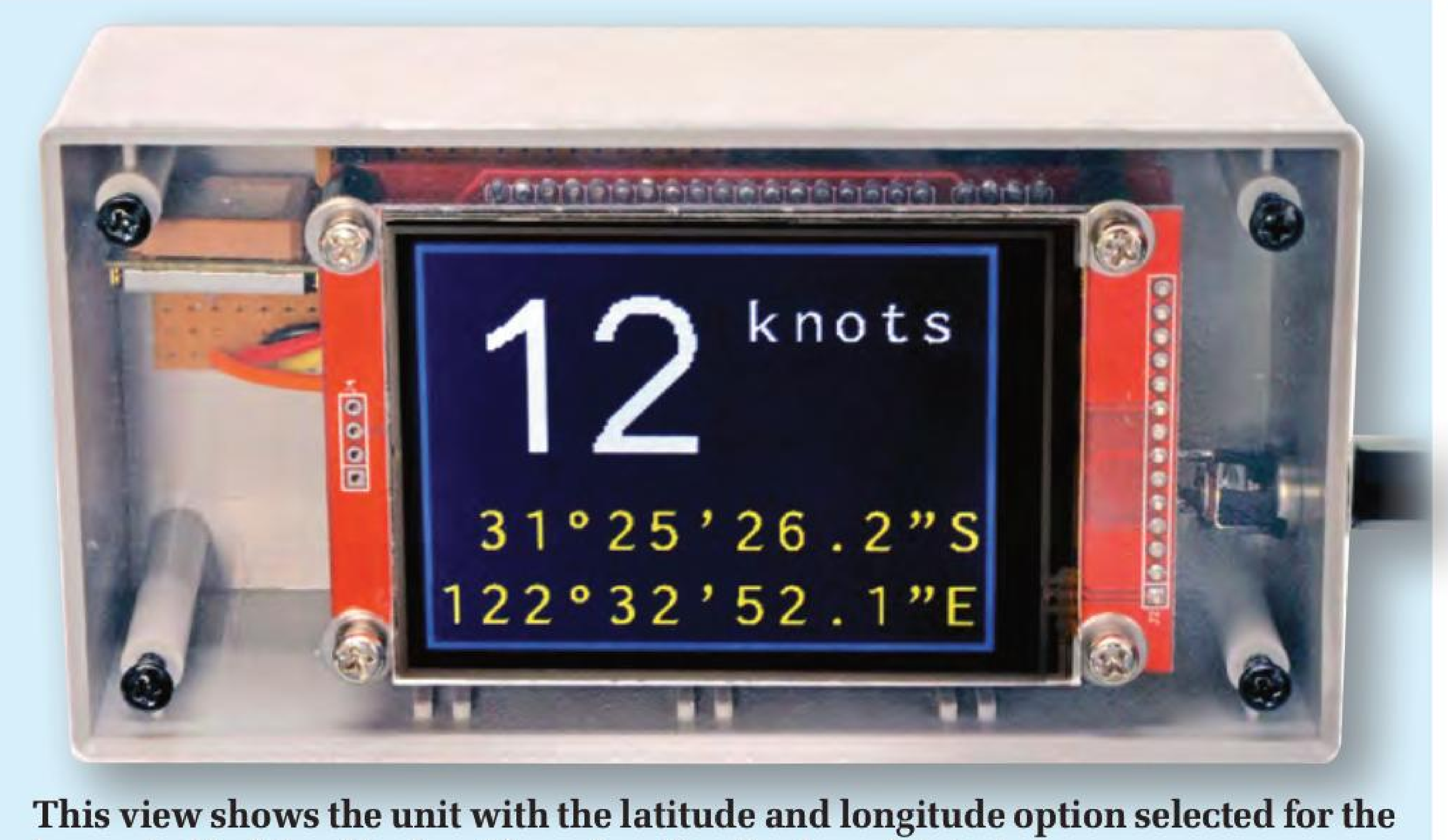


This view shows the unit with the latitude and longitude option selected for the lower half of the display. Changing the displayed data is easy.

of the UB3 ABS box. The red wire is then soldered to one pin of a 4-pin female header connector, while the black wire goes to the other end – see Fig.4.

The other two wires in the USB cable (generally green and white) can be cut short as they are not needed.

Once the cable has been completed, plug the header into CON1 on the *BackPack* PCB, making sure that the red wire goes to the +5V pin. The cable gland can then be tightened to make a moisture-proof seal. As an added measure, some silicone sealant can also be smeared around the cable gland inside the case.

Note that the cable gland must be fitted close to the rear of the case, so that it doesn't interfere with the *BackPack*

Understanding a GPS module's output

One of the difficulties when troubleshooting a project using a GPS module is understanding what the data coming from such a module should look like. The following is the output that we recorded from the Fastrax UP501 module. These six lines are repeated every second.

First, this is the output when the module was searching for satellites (ie, it did not have a 'lock' on our position):

```
$GPGGA,232048.764,,,,,0,3,,,M,,M,,*41
$GPGSA,A,1,,,,,,,,,,,,,,,*1E
$GPGSV,3,1,10,19,76,148,20,17,49,140,18,06,41,044,24,24,40,226,*7A
$GPGSV,3,2,10,15,28,286,,13,27,331,,28,25,106,,12,22,249,*7B
$GPGSV,3,3,10,02,18,001,,30,09,043,*7F
$GPRMC,232048.764,V,,,,,0.27,0.00,150216,,,N*43
```

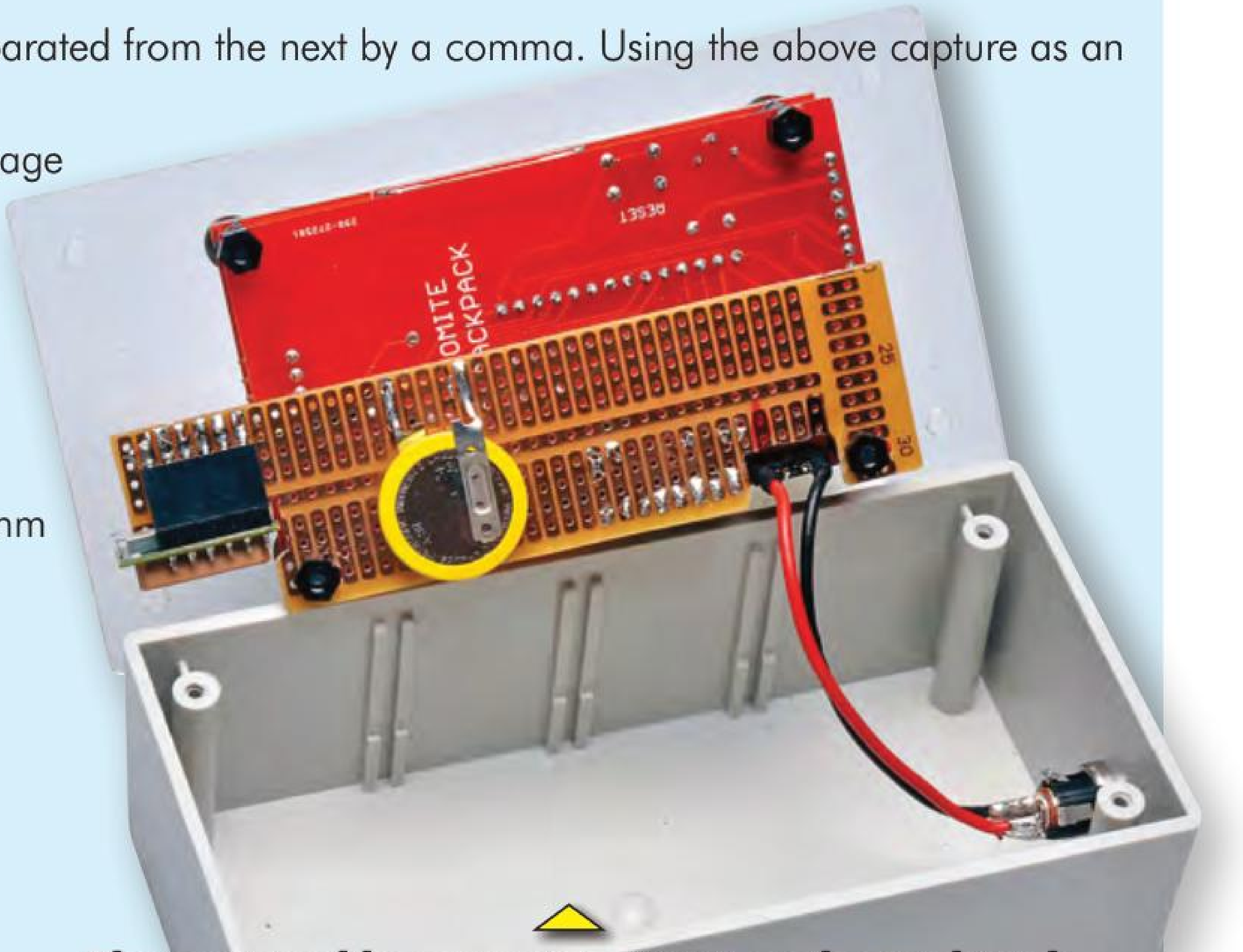
And this is the output when it did have a lock and was producing valid data:

```
$GPGGA,231719.000,3411.5204,S,14135.6619,E,1,9,0.90,3.2,M,5.1,M,,*75
$GPGSA,A,3,02,13,17,30,15,24,06,12,28,,,,2.43,0.90,2.25*03
$GPGSV,3,1,11,19,77,147,,17,51,140,16,06,40,043,29,24,39,226,10*74
$GPGSV,3,2,11,13,28,330,16,15,28,284,14,28,26,107,21,12,21,251,14*7A
$GPGSV,3,3,11,02,16,001,19,30,11,043,15,01,01,148,*48
$GPRMC,231719.000,A,3411.5204,S,14135.6619,E,9.62,302.03,150216,,,A*75
```

Each line (called a message) provides a set of data such as the current location, the number of satellites being used, etc. For the Touch-Screen Boat Computer, we only use the RMC message, which is the last line in the above listing. RMC stands for 'Recommended Minimum Specific GNSS Data' and is specified in the NMEA standard as mandatory; therefore, all modules from any manufacturer should generate at least this message.

Each message line is broken down into fields, with each field separated from the next by a comma. Using the above capture as an example, this is the meaning of each field:

$GPRMC:	The header designating that this is an RMC message
231719.000:	The UTC time in the format hhmmss.sss
A:	A flag indicating if the module has a satellite 'lock'. A = lock or V = searching
3411.5204:	The current latitude in the format ddmm.mmmm
S:	North/South indicator
14135.6619:	The current longitude in the format dddmm.mmmm
E:	East/West indicator
9.62:	Current speed in knots
302.03:	The current heading in degrees
150216:	The UTC date in the format ddmmyy
,,,:	These two fields are for specialised data not used (ie, empty) in most modules
A:	Another specialised field indicating the mode of the GPS module
***75:**	The * character marks the end of the data and the following two digits are the checksum



The power cable connects to CON1 on the *BackPack* PCB via a 4-way header. We fitted a DC socket to the prototype but it's preferable to run the cable through a cable gland and seal it with silicone (see text).

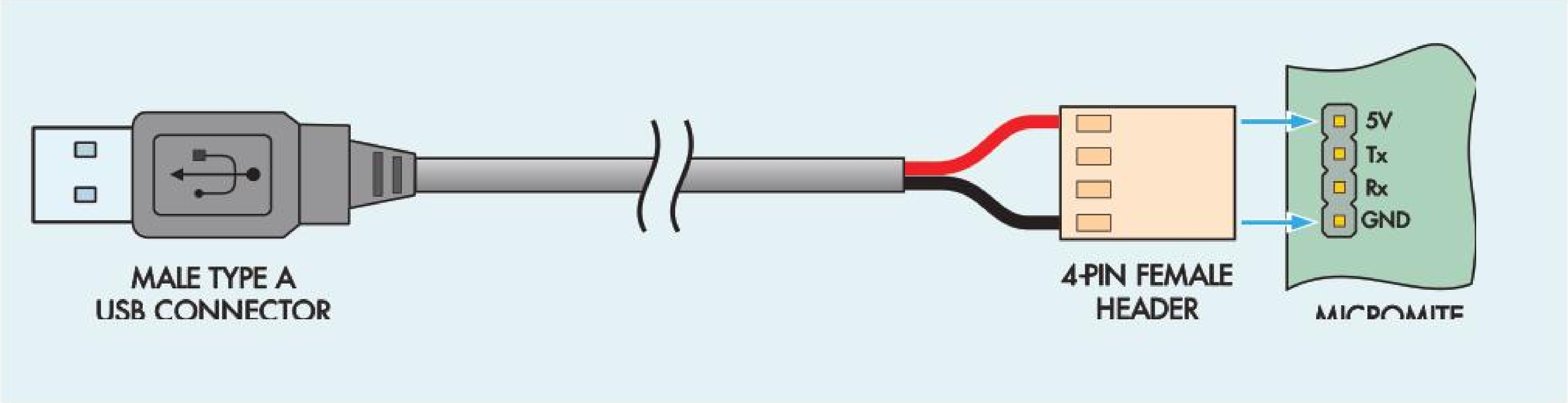


Fig.4: the *Touch-Screen Boat Computer* is powered from a 5V USB charger that's either plugged into a 12V cigarette lighter socket or wired permanently into the boat's power supply (see text). To make a suitable power cable, cut off one end of a USB cable, thread the cut end through a cable gland in the side of the case and solder it to a 4-pin female header connector.

PCB. Note also that you will need to secure the lid using four No.4 × 10mm self-tapping screws (the original case screws are too short with the new lid).

Finally, for the sake of convenience and to allow us to use the power cable made for the *Garage Parking Sensor*, we fitted a DC socket to the prototype. However, this arrangement is not moisture-proof and we strongly recommend running the power cable through a cable gland, as described above.

New to the Micromite?

For a great introduction to the Micromite that explains what it is, how it works and what it can do for you, see our three-part series *Meet the mighty Micromite* in the February-April 2017 issues of *EPE*.

Parts List

Micromite LCD BackPack Unit

1 PCB, available from the *EPE PCB Service*, coded 07102122, 86 × 50mm (for 2.8-inch LCD)
1 ILI9341-based LCD, 320 × 240 pixels, 2.8-inch diagonal
1 UB3 ABS box, 130 × 67 × 43mm
1 laser-cut clear acrylic lid to suit UB3 box
1 4-pin tactile switch, through-hole
1 100Ω vertical-mount side adjust trimpot
1 28-pin DIL low-profile IC socket
1 4-pin 0.1-inch male header (CON1)
1 18-pin 0.1-inch male header (CON2)
1 14-pin 0.1-inch female header socket (CON3)
1 6-pin 0.1-inch right-angle male header (CON4)
1 4-pin 0.1-inch female header
1 8-pin 0.1-inch female header
4 M3 × 12mm tapped spacers
2 M3 × 6mm machine screws

Semiconductors

1 PIC32MX170F256B-50I/SP microcontroller programmed with **BoatComputerFull.hex** (IC1) – see text. Note: a PIC32-MX170F256B-I/SP can also be used but will be limited to 40MHz
1 Microchip MCP1700-3302E/TO voltage regulator (REG1)

Capacitors

1 47µF 16V tantalum or SMD ceramic (3216/1206)
2 10µF 16V tantalum or SMD ceramic (3216/1206)
2 100nF monolithic ceramic

Resistors (0.25W 5%)

1 10kΩ

Cable parts

1 USB cable with a male type A connector (length to suit)
1 4-pin 0.1-inch female header

Additional parts for the Boat Computer

1 3.3V or 5V GPS module (available from Online Shop – see below)
1 1N4004 silicon diode (D1)
1 1kΩ resistor (0.25W, 5%) (see text)
1 USB cable with a male type A connector on one end
1 4-pin 0.1-inch female header
1 3-6.5mm cable gland (Jaycar HP0720, Altronics H4304A)
4 No.4 × 10mm self-tapping screws
2 M3 × 12mm tapped spacers
4 M3 × 20mm machine screws
2 M3 nuts
4 M3 spring washers

Where to buy parts

There is a UK online shop for all things Micromite-related – including the *LCD Backpack*, the USB-to-serial converter and a GPS module. It is run by Phil Boyce at: **micromite.org**

We strongly recommend you make **micromite.org** your first port of call when shopping for all Micromite project components. Phil can supply kits, programmed ICs, PCBs and many of the sensors and other devices mentioned in recent articles – in fact, just about anything you could want for your Micromite endeavours.

Phil is not just another online vendor of assorted silicon. He works closely with Geoff Graham and is very knowledgeable about the whole series of Micromite microcontrollers.

Firmware updates

For firmware updates for the Micromite and the *Touch-Screen Boat Computer*, please check the author's website at:
geoffg.net/micromite.html

Looking to advertise?
Contact Stewart Kearn on:
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or email
stewart.kearn@wimborne.co.uk

Who left that door open again?!

FRIDGE/FREEZER ALARM

We've all done it: opened the fridge or freezer door and then not closed it properly. That can cost you: the food could spoil or at the very least, the refrigerator could run continuously and you'll waste a lot of electricity.

By John Clarke

Build this *Fridge Door Alarm* and it will warn you whenever the door is open or ajar. Not only that, the cost to build it is far less than if you lose a fridge full of food due to spoilage.

Even the self-closing doors on modern fridges are not completely foolproof; there might be an obstruction inside the door, because an item inside the compartment has moved or fallen over, or because the compartment is too full. It helps, of course, if the fridge is slightly tilted back to 'encourage' the doors to close by themselves.

Whatever fridge you have, our *Fridge Door Alarm* is most useful. It warns when the door of the refrigerator or freezer is left open for longer than the preset time. It is great for indicating when someone is standing with the door open for too long and is a real asset in warning when the door looks shut but is still partially ajar.

The fridge alarm has an LDR (light-dependent resistor) which responds to ambient light. So it will respond to the fridge light which will be on even if the door is barely ajar.

And the circuit is so sensitive it will work in a freezer compartment, which will normally not have an internal light (Note: recent model fridges often do have white LED illumination in the freezer compartment). As long as there is some ambient light that the *Fridge Door Alarm* can detect, then it will operate.

The alarm will sound if the light is present for longer than the preset period and will continue to sound until the door is closed. In practice, the preset period is set so that in normal use the alarm will not sound. It will then sound when the door is left wide open for too long or if left slightly ajar.

Note that the alarm cannot be used with display refrigerators or freezers that have glass doors – that is, unless the *Fridge Door Alarm* light sensor can be positioned so that it is covered over by the glass door frame when the door is closed.

Does the light really go off?

Do you or members of your family have doubts whether the fridge light really goes off when the door is closed? Does the little man in the fridge really do his job? Or is he sitting in there shivering, trying to keep warm under the light?

This *Fridge Door Alarm* will finally dispel any doubts on this score. If you open the door and can hear the alarm sounding immediately, it means that the light has remained on while the door was closed. Sceptics may then say it's the fridge alarm itself that does not cease making alarm sounds and so is immediately heard when the door is opened. Well, stick the

Unit Pak
Specification MIL-D-3464
Desiccare, Inc.
www.desiccare.com

FEATURES

- Powered by a Lithium button cell
- LED brightness indicates cell condition
- Low current drain (~2.5μA)
- Two alarm sound options
- Adjustable alarm onset period (~2-180s)

alarm in your pocket; the alarm will stop sounding!

The *Fridge Door Alarm* is designed to be housed in a small transparent box or more simply, a sealed plastic bag, and powered with a 3V lithium button cell.

It is placed in the freezer or refrigerator near the door opening, so it can 'see' light from the internal lamp *and* from outside the compartment.

Circuit details

As can be seen in the diagram of Fig.1, there is not much to the circuit; a PIC microcontroller, an LDR, a piezo sounder and not much else. The 3V lithium button cell is switched via jumper link JP1. Taking up less room than a switch on the PCB, the link can be removed (and placed on one of the jumper pins – so you don't lose it) to disable the alarm when not in use. The circuit draws only 2.5μA when lying dormant in the fridge in darkness, rising to about 0.5mA when the alarm is sounding.

Most of the time, the PIC12F675 microcontroller (IC1) is asleep and it wakes every 2.3 seconds to monitor the LDR and to power up its internal oscillator, which runs at 4MHz.

Normally, IC1's GP1 output is set high (3V) and so there is no current through the 3.3MΩ resistor and the LDR. When IC1 is awake, it sets output GP1 low (0V) and the LDR forms a voltage divider in conjunction with the 3.3MΩ resistor across the 3V supply. The voltage across LDR1 is monitored at input GP3, pin 4.

In darkness, the LDR resistance is very high (above 10MΩ) so the voltage at input GP3 is more than 2V due to the voltage divider action of the LDR and the 3.3MΩ resistor. This voltage level tells IC1 that the *Fridge Door Alarm* is in the dark. If the fridge door is opened, light will cause the LDR to drop in resistance, down to around 10kΩ, which produces a low level at the GP3 input and IC1 now 'sees' the light.

Diode D1 is included as a safety measure to prevent damage to IC1 if the cell holder is installed the wrong

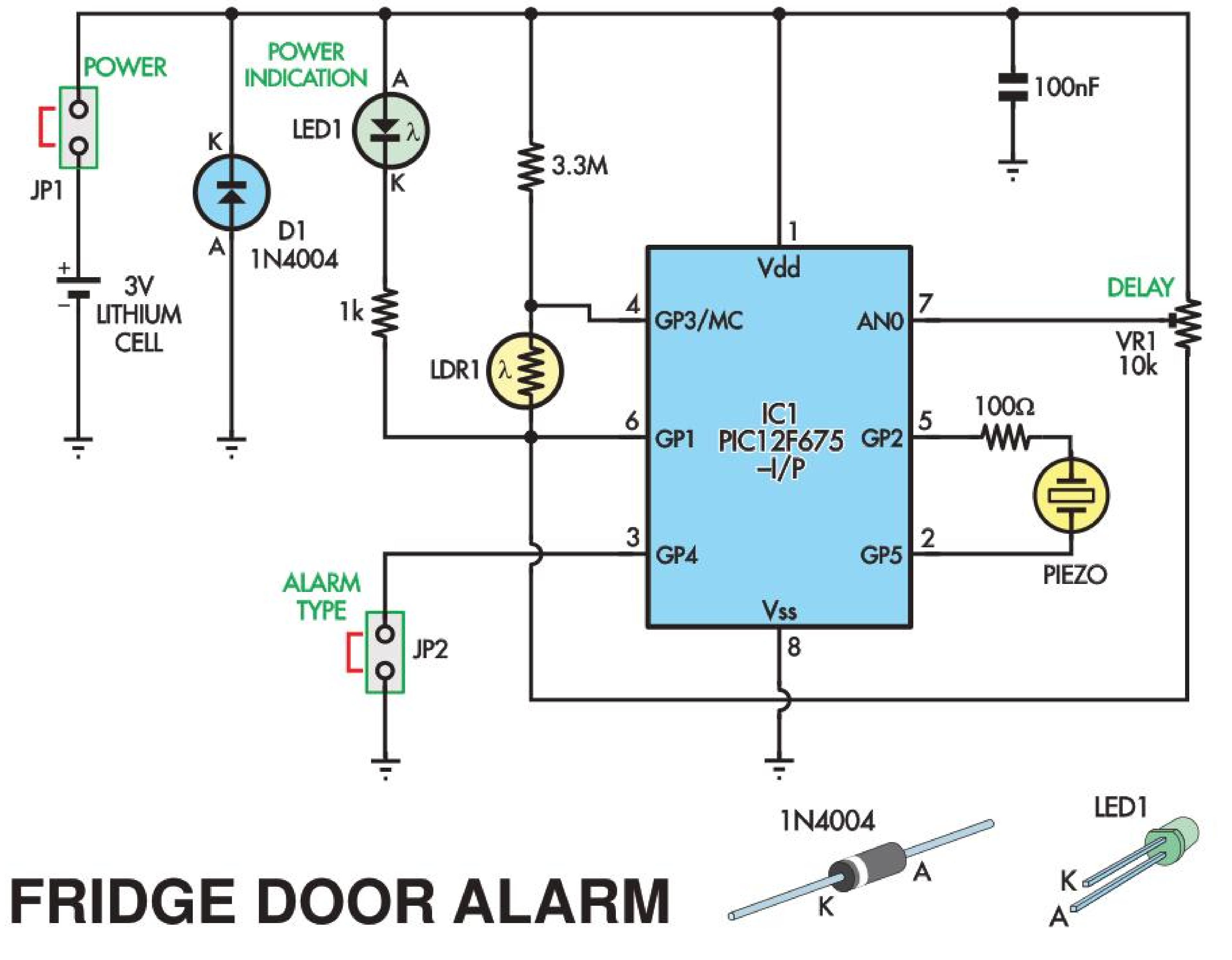

POWER
JP1
POWER INDICATION
A
K
LED1
λ
K
A
D1
1N4004
+
–
3V LITHIUM CELL
1k
3.3M
LDR1
100nF
1
Vdd
4
GP3/MC
AN0
7
DELAY
VR1
10k
IC1
PIC12F675
–I/P
6
GP1
GP2
5
100Ω
PIEZO
3
GP4
GP5
2
Vss
8
ALARM TYPE
JP2
1N4004
A
K
LED1
K
A
FRIDGE DOOR ALARM

Fig.1: there's not much to the circuit – a PIC microcontroller, an LDR (the component which actually tells the little man in the fridge that the light is still on . . .) a piezo to make noise – and very little else. You can change the alarm sound with JP2.

way round. If the polarity is wrong, diode D1 will shunt the reverse current. If the cell holder is installed correctly, then because of the way the CR2032 cell is made, there is no way that it can be inserted back to front. (At least that is true for the particular cell holder we used).

GP1's output is only held low for just long enough to monitor the resistance of the LDR. GP1 then returns high to save power. When GP1 is low, LED1 lights to indicate that power is applied to the circuit. The LED brightness also provides an indication of the cell voltage.

VR1 is also connected to the GP1 output again to save power. This allows one side of this trimpot to be taken low. The other end of the trimpot is connected to the 3V supply. The AN0 input monitors the voltage setting for VR1's wiper whenever GP1 is low. VR1's wiper can be set to show a voltage anywhere between 0V and the 3V supply. The voltage setting determines the delay, which is adjustable from 2 to 180 seconds (three minutes).

Notes on the software

Note that the GP3 input in many projects is often configured as the MCLR input (master clear), which allows the microcontroller to have an external power-on reset. However, for our circuit we need this as a general purpose input for monitoring the LDR.

When MCLR is set up as an input, the MCLR operation is switched to an internal connection within the microcontroller so that the master clear power-on-reset function is not lost. One disadvantage of using this as a general purpose input is that it is not a Schmitt trigger input.

The lack of a Schmitt trigger input at GP3 can mean that at a particular ambient light level, the input to GP3 could be read as either a high or low input level by IC1's software. At this threshold, the *Fridge Door Alarm* could produce strange alarm sounds as IC1's software switches the alarm on and off, undecided as to the ambient light level.

We solved this by making sure that once the *Fridge Door Alarm* is switched on (in the light), it is not switched off until the ambient light reaches a significantly lower level. This difference in level is called 'hysteresis'.

Hysteresis is implemented by pulsing the GP1 output momentarily high when checking for a high ambient light level. High ambient light means that the LDR's resistance is low, so the GP3 input is a low voltage. The momentary high pulse level effectively raises the average GP3 voltage slightly since this pulse is filtered with the internal capacitance at the GP3 input of 50pF or less. The raised voltage means that the LDR is required to have a lower resistance (ie, have more light shining on it) to bring the GP3 voltage low enough for a low input reading by IC1.

The second disadvantage of using the MCLR pin as a general purpose input is that there can be a problem when programming the microcontroller. This problem occurs when the internal oscillator is also used to run the microcontroller (which we do). We solved this problem in the software and the solution is discussed later under the 'programming' subheading.

Output drivers

Outputs GP2 and GP5 on IC1 are used to drive the piezo transducer in bridge mode, ie, with the two outputs working in a complementary manner. So when GP2 is high, GP5 is low; and when GP2 is taken low, output GP5 is taken high. This provides a full 3V peak square wave drive to the transducer. A 100Ω resistor limits peak currents into the capacitance of the piezoelectric transducer at the switching of the outputs. (See oscilloscope trace and caption).

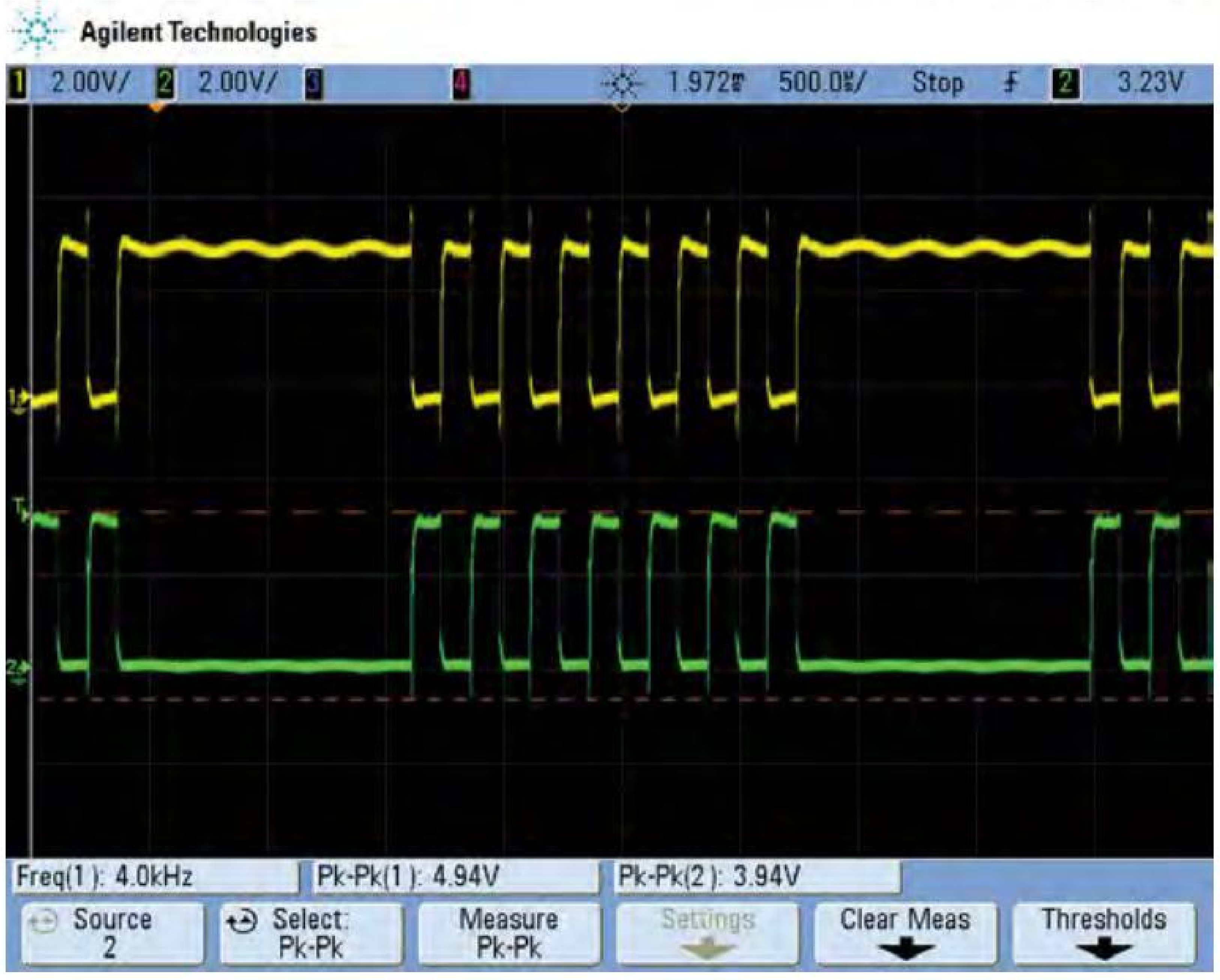
Normally, the GP4 input is set as a low output without pull-up to save on power drawn from the cell. However, whenever IC1 checks the input level, GP4 is set as an input, with an internal pull-up current source enabled. With no jumper link at JP2, the input is pulled high via this internal pull-up. When a jumper link is installed, the input is held low. This determines the alarm sound produced. Note that the GP4 input state is checked just before the alarm sounds.

The alarm can be either a short (50ms) 4kHz beep that repeats once per second (JP2 open) or a chirping cricket sound (JP2 installed). See Scope1-Scope3 images for more details.

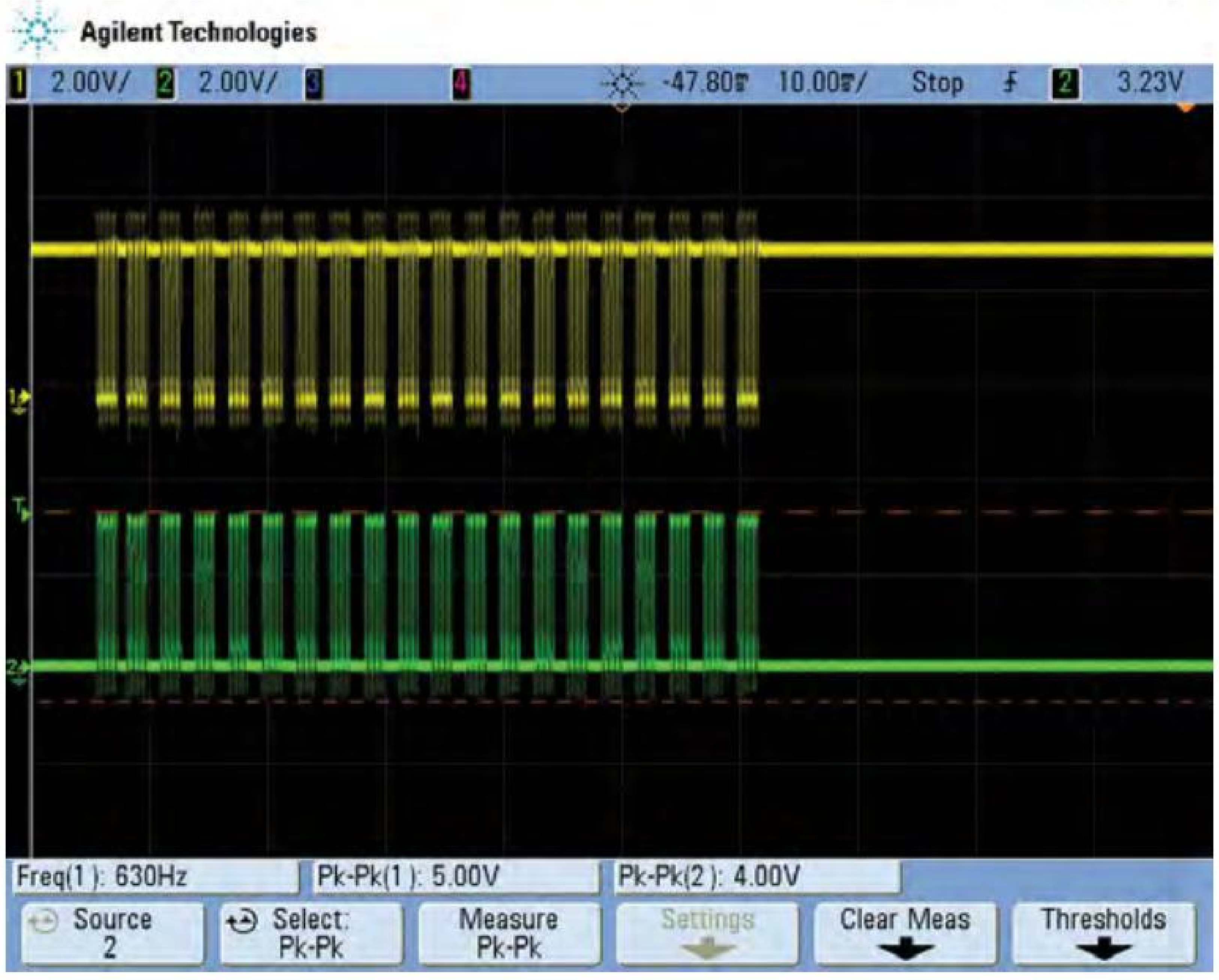
Construction

The *Fridge Door Alarm* is constructed on a PCB coded 03104161, measuring 30 × 65mm. This PCB is available from the *EPE PCB Service*. It is presented as a bare PCB which can be sealed inside a clear plastic bag, but we have made provision for mounting it inside a small plastic case.

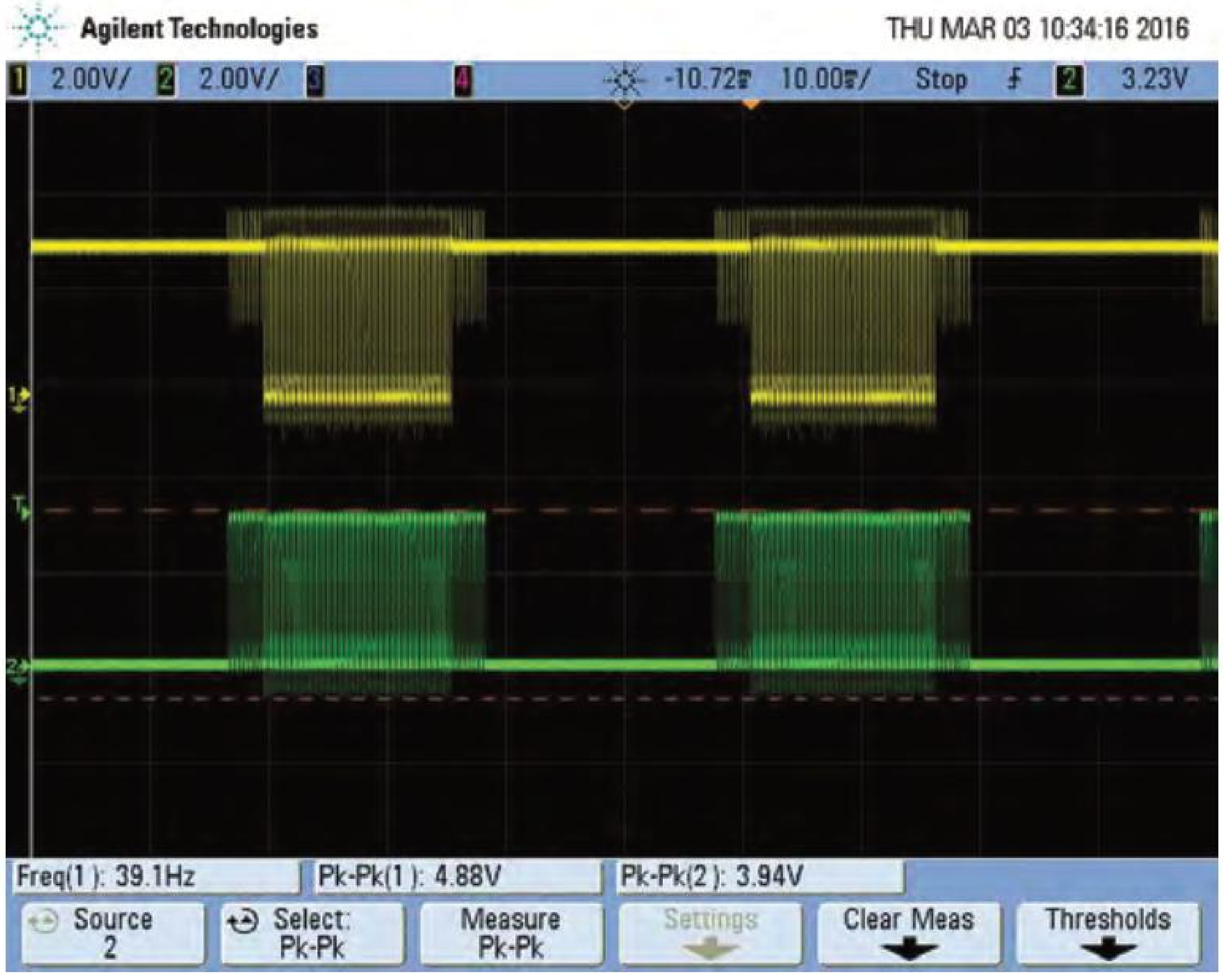
Fig.2 shows the PCB overlay. Begin construction by installing the three



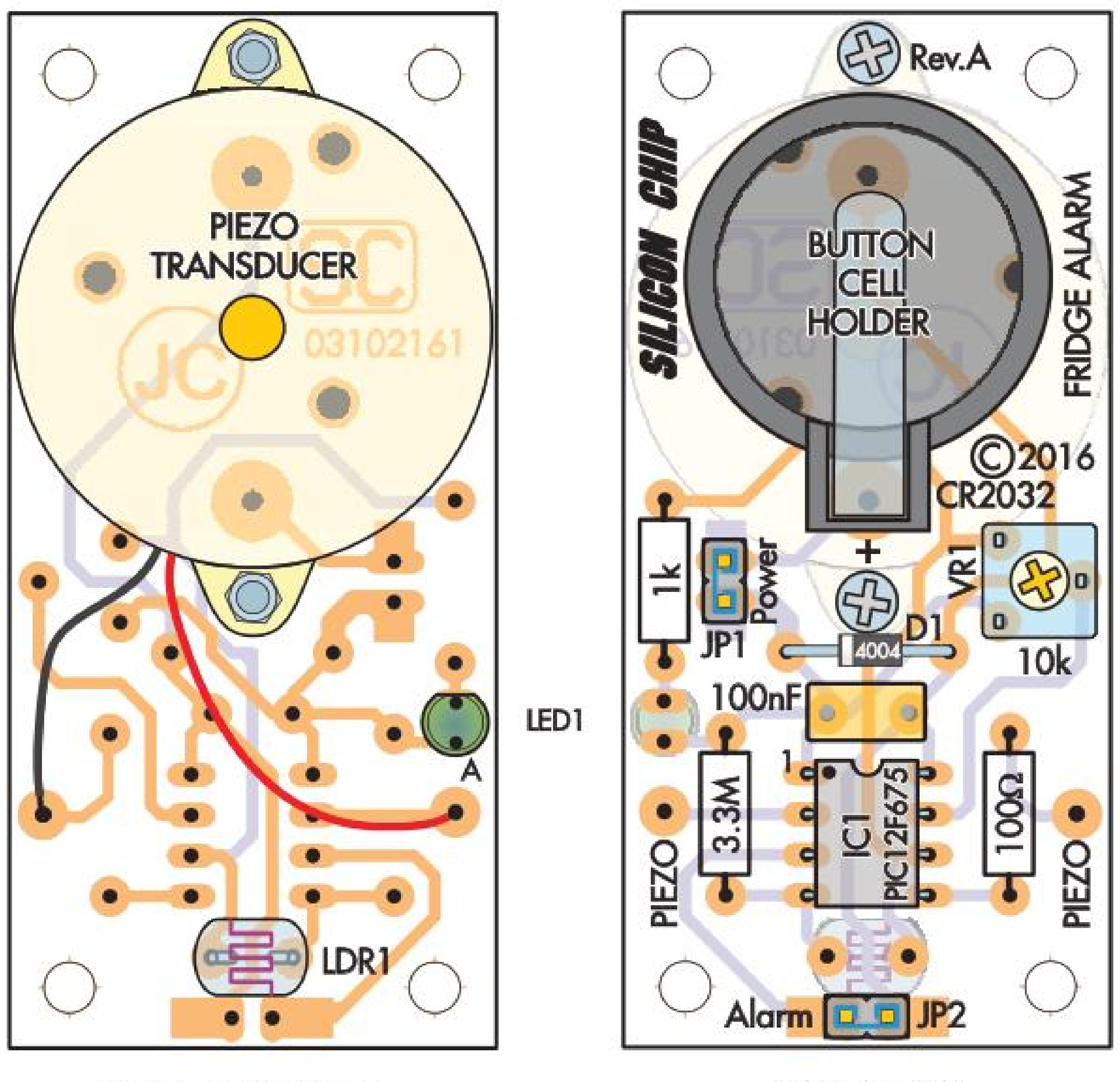
Scope1: This oscilloscope screen shows the drive signals to the piezo transducer, measured at pins 2 and 5 of the PIC microcontroller. The drive frequency is 4kHz. In effect, the total voltage across the transducer is the difference between the two out-of-phase signals, resulting in twice the voltage from pin 2 or pin 5.



Scope2: Taken at a much slower sweep speed than Scope1, this shows the same simple chirp alarm signal, which consists of 20ms bursts of 4kHz at regular intervals. Note that the drive signal from each microcontroller output is essentially 'square', but the trailing edges do have significant ringing.

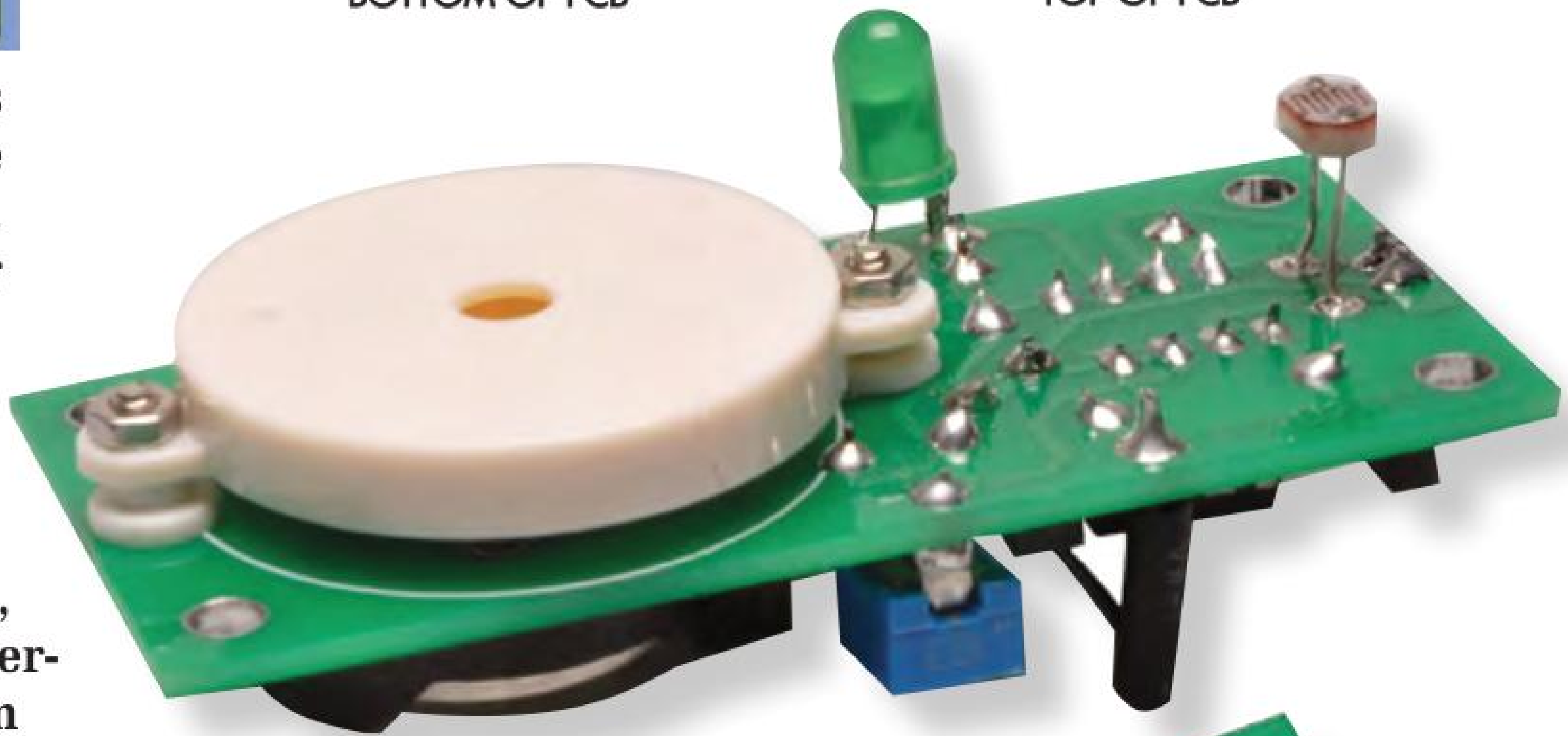

Agilent Technologies
THU MAR 03 10:34:16 2016
1 2.00V/ 2 2.00V/ 3 4
-10.72s 10.00s/ Stop ƒ 2 3.23V
Freq(1): 39.1Hz
Pk-Pk(1): 4.88V
Pk-Pk(2): 3.94V
Source 2
Select: Pk-Pk
Measure Pk-Pk
Settings
Clear Meas
Thresholds

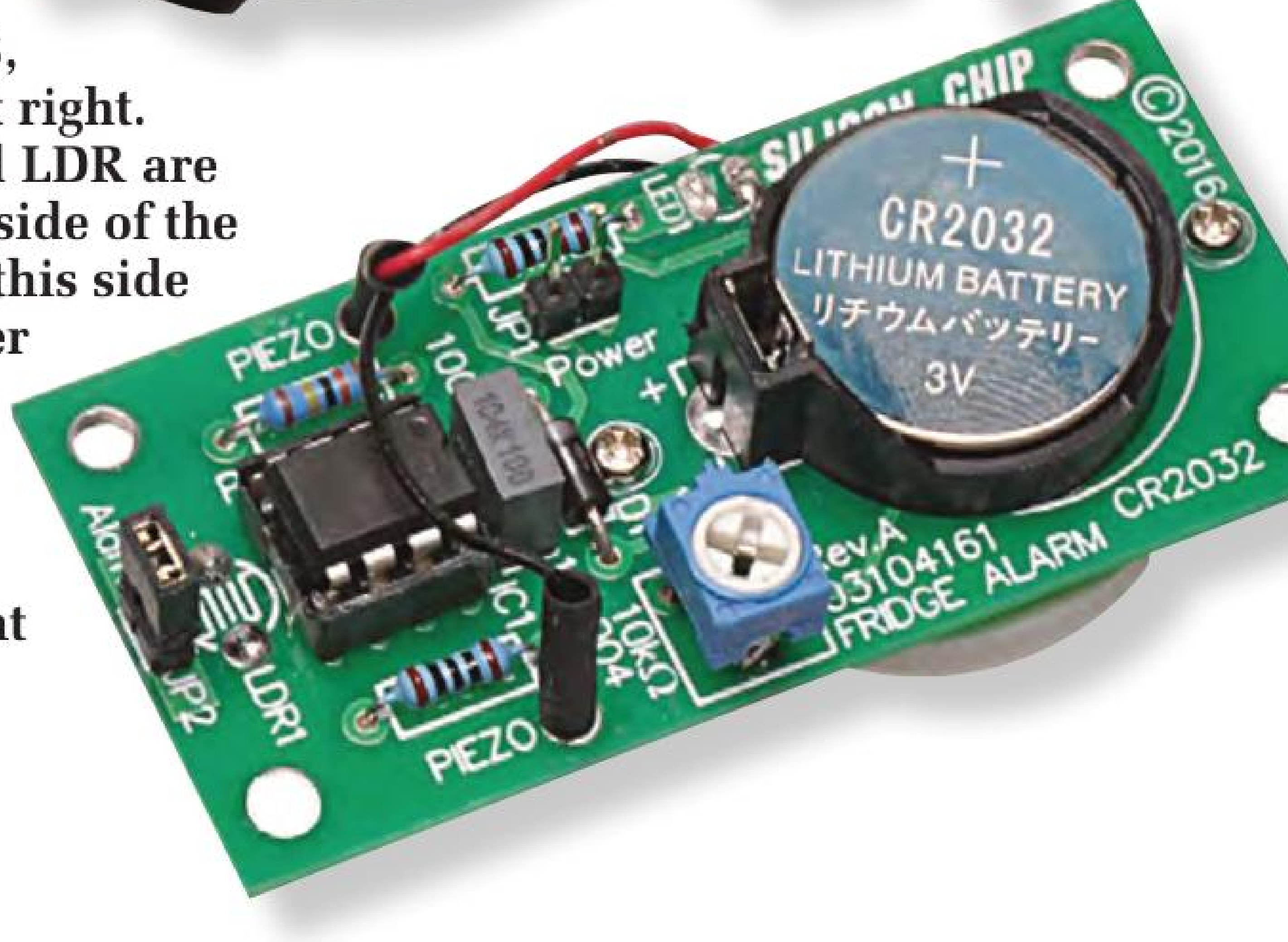
Scope3: Taken at the same sweep speed as in Scope2, this is the more complex 'cricket' alarm sound which we found to be more arresting (insistent, irritating, annoying – your choice). You can choose either alarm sound by having link JP2 in or out of circuit.


PIEZO TRANSDUCER
03102161
LED1
A
LDR1
Rev.A
SILICON CHIP
BUTTON CELL HOLDER
FRIDGE ALARM
©2016
CR2032
1k
Power
JP1
+
VR1
D1
4004
10k
100nF
1
3.3M
IC1
PIC12F675
100Ω
PIEZO
PIEZO
Alarm
JP2

BOTTOM OF PCB

TOP OF PCB




SILICON CHIP
©2016
CR2032
LITHIUM BATTERY
3V
PIEZO
Power
Rev.A
03104161
FRIDGE ALARM
CR2032
LDR1
JP2
PIEZO

Above right: Fig.2, the component overlays for the bottom and top sides of the PCB, with matching photos at right. Only the piezo, LED and LDR are mounted on the bottom side of the PCB; it is intended that this side aim out the fridge/freezer door. As explained later in the text, the PCB was enclosed in a zip-loc bag with a desiccant to help prevent condensation.

resistors, using a multimeter to check the value of each before inserting it into the PCB.

Diode D1 can now be installed, taking care to orient it correctly. Fit the IC socket next, orienting its pin 1 notch as shown in Fig.2, followed by the lone 100nF capacitor (either way around) and the trimpot.

Next, solder in the 2-way pin headers for JP1 and JP2, followed by the cell holder. Make sure the plus terminal is oriented toward diode D1 on the PCB.

The piezo transducer is mounted on the underside of the PCB, supported on TO-220 insulating bushes used as spacers and secured with short M2 screws and nuts. The wires can be soldered to the underside of the PCB (the positions are marked 'PIEZO') or brought around to the top of the PCB. We used PC stakes for the piezo transducer wiring on the top side, as this allows provision for heatshrink tubing over the wires and PC stakes help prevent the wires from breaking off.

While the piezo transducer will probably come with red and black wires, the connections required are not polarised and it doesn't matter which wire is used for each 'PIEZO' position.

LED1 is also mounted on the bottom side of the PCB. Make sure the longer lead of the LED (the anode) is inserted in the 'A' position on the PCB. Then fit the LDR, about 10mm above the PCB surface, also on the underside. Its polarity is unimportant.

If you intend to program the PIC yourself, download 0310216A.HEX from the *EPE* website and flash the PIC chip with it. See the section on programming for details.

IC1 can now be plugged into its socket, with pin 1 towards the notched end, near the centre of the board.

You can now install the CR2032 cell in its holder and place the jumper link onto the 2-way header (JPI). If all is well, the LED will momentarily flash after about three seconds to indicate that power has been connected.

A brief flash of the LED also occurs when a high light level is detected. Then the *Fridge Door Alarm* will sound the alarm after the delay set by VR1. The alarm should stop when the LDR is in darkness. The delay can be adjusted from between two and 180 seconds, with two seconds when VR1's wiper is set fully anticlockwise and 180s when set fully clockwise. Mid-setting provides about a 90s delay.

Note that the 2-second delay will be affected by the sampling period of the LDR that occurs every 2.3s. So the alarm may start anywhere between two and 4.3 seconds after light is detected by the LDR. As the delay is adjusted to higher periods, the variation in delay due to the sampling period becomes less significant.

Note that you can keep tabs on the lithium cell condition by observing the LED. If it flashes brightly as the fridge door is opened, then the cell is OK. As the cell discharges, the LED will become quite dim.

Programming

If you are programming the microcontroller yourself, you may be presented with a warning by the programmer stating that programming is not supported when both the MCLR is set as a general purpose input and with the internal oscillator set.

However, you will be able to program the microcontroller successfully, just ignore the warning.

Parts list – Fridge/Freezer Alarm

1 double-sided PCB, available from the *EPE PCB Service*, coded 03104161, 30 × 65mm
1 small zip-loc plastic bag
1 packet dry silica gel desiccant
1 20mm button cell holder
1 CR2032 lithium cell (3V)
1 30mm-diameter piezo transducer
1 10kΩ light-dependent resistor (LDR1)
1 DIL8 IC socket
2 M2 × 8mm screws with nuts
2 TO-220 insulating bushes
2 2-way pin headers (2.54mm pin spacing) (JP1,JP2)
2 jumper shunts
2 PC stakes
1 25mm length of 2mm diameter heatshrink tubing

Semiconductors
1 PIC12F675-I/P programmed with 0310216A.hex (IC1)
1 1N4004 diode (D1)
1 3mm green high brightness LED (LED1)

Capacitor
1 100nF 63V or 100V MKT polyester

Resistors (0.25W, 1%)
1 3.3MΩ   1 1kΩ   1 100Ω
1 10kΩ miniature horizontal trimpot (VR1)

Extra parts for mounting in box
1 UB5 Jiffy box
4 M3 × 12mm tapped spacers
4 M3 × 6mm machine screws
4 M3 × 6-9mm countersunk screws

That's because any problems associated with this configuration are already solved by a software solution. Read on if you want more details.

As mentioned, we set MCLR as a general purpose input and utilise the internal oscillator within IC1. This can present problems for a programmer during the process of verifying the software code after programming.

The problem lies in the fact that as soon as the microcontroller is programmed, it will begin executing its program. A typical program initially sets up the microcontroller with the general purpose (GP) lines set as inputs or outputs (I/O).

This conflicts with the programmer needing to use the clock and data programming I/O lines for program verification. This problem does not happen if the MCLR pin is set as the external MCLR input because the programmer then has control over the microcontroller, stopping it from executing the programmed code.

Note also that in order to run the code, the microcontroller needs to operate from the internal oscillator instead of an external crystal, RC oscillator or clock signal.

The programming problem is solved in the software provided by including a three-second delay at the start of the program. This delay is before the I/O lines are set as inputs or outputs.

The I/O lines therefore remain as high-impedance inputs while the programmer verifies the internally programmed code using the clock and data programming lines.

A warning from the programmer will still be issued, but the microcontroller can be programmed successfully and correctly verified by the programmer.

Note that the PIC12F675 also needs special programming due to the fact that it has an oscillator calibration value (OSCAL) that is held within the PIC's memory.

This calibration value is individually programmed into each PIC by the manufacturer and provides a value that allows the PIC to run at an accurate 4MHz rate.

This value must be read before erasure and programming so that it can be included with the rest of the code during programming.

If this procedure is not done, then the oscillator could be off frequency and that will have an effect on the *Fridge Door Alarm* sound.

Most PIC programmers will automatically cater for this OSCAL value, but it is worthwhile checking if your programmer correctly handles this. Finally, be aware that the PIC12F675 requires a 5V supply for programming, even though it happily runs at 3V in the circuit.

In use

Condensation will always be a problem in a fridge or freezer. To help overcome this, once we confirmed it was working correctly, we sealed the unit inside a 'zip-loc' plastic bag and included a bag of desiccant (silica gel) to help absorb moisture.

You should be able to find some silica gel – we're always throwing it away as it comes packed with a lot of equipment such as photo gear, where moisture can be a problem.

Because of the ultra-low current drain, battery life should be not much less than the cell's shelf-life.

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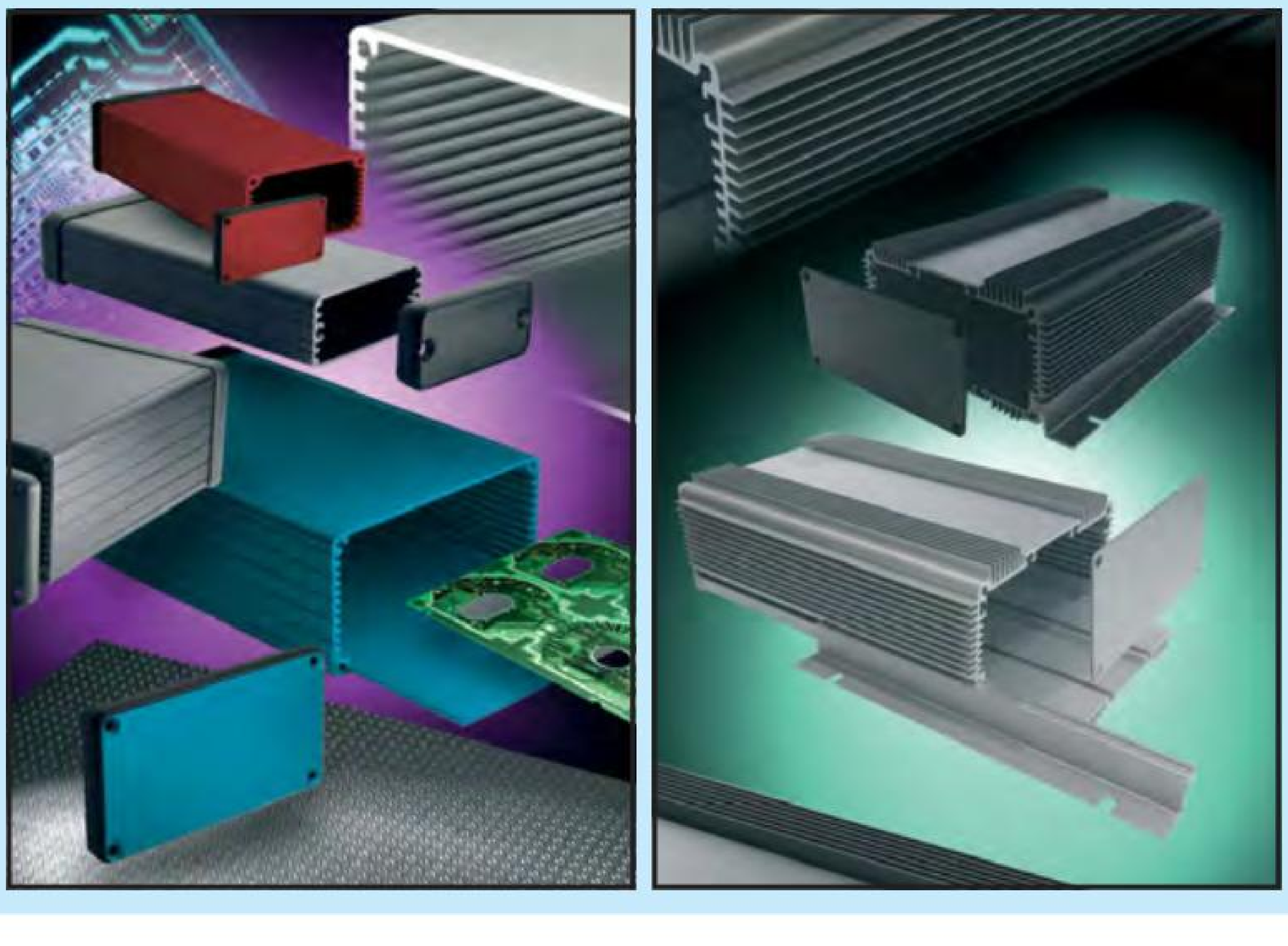


Win a Microchip PIC32MK1024GP Development Kit

EVERYDAY PRACTICAL ELECTRONICS is offering its readers the chance to win a Microchip PIC32MK1024GP Development Board (DM320106). The PIC32MK GP Development Kit offers a low-cost solution for developers looking to build projects with the PIC32MK series of devices, featuring a rich assortment of CAN, USB, ADC and GPIO-type inputs. This board also includes a Soloman Systec SSD1963 graphics driver and 30-pin connector to enable graphics applications with available LCD panels.

The PIC32MK devices have peripheral block support for MathWorks® MATLAB® and Simulink®, as well as open-source-based Scilab® for customers interested in numerical-computation environments for engineering and scientific applications. All GP devices feature a 120MHz 32-bit core that supports Digital Signal Processor (DSP) instructions. Additionally, to ease control algorithm development, a double-precision floating-point unit is integrated into the MCU core, enabling customers to utilise floating-point-based modeling and simulation tools for code development.

This board features include: • 4 CAN 2.0 ports with transceivers, 2 supporting DB9 type connectors • Dual full-speed USB supporting simultaneous host and/or device, including a USB-C hardware compatible connector • Dual MikroBUS CLICK headers supporting the wide array of CLICK Boards • One XC32 header for supporting Microchip add-on modules for audio and bluetooth • 30-pin general IO header for analogue and digital signal connections.

Additionally, this board supports USB programming and debug via the on-board PIC Kit On Board (PKOB) eliminating the need for external programming hardware.

WORTH
$120.00
(approx. £93.00)
EACH

HOW TO ENTER

For your chance to win a Microchip PIC32MK1024GPE Development Board, visit **http://www.microchip-comps.com/epe-32mkgp** and enter your details in the online entry form.

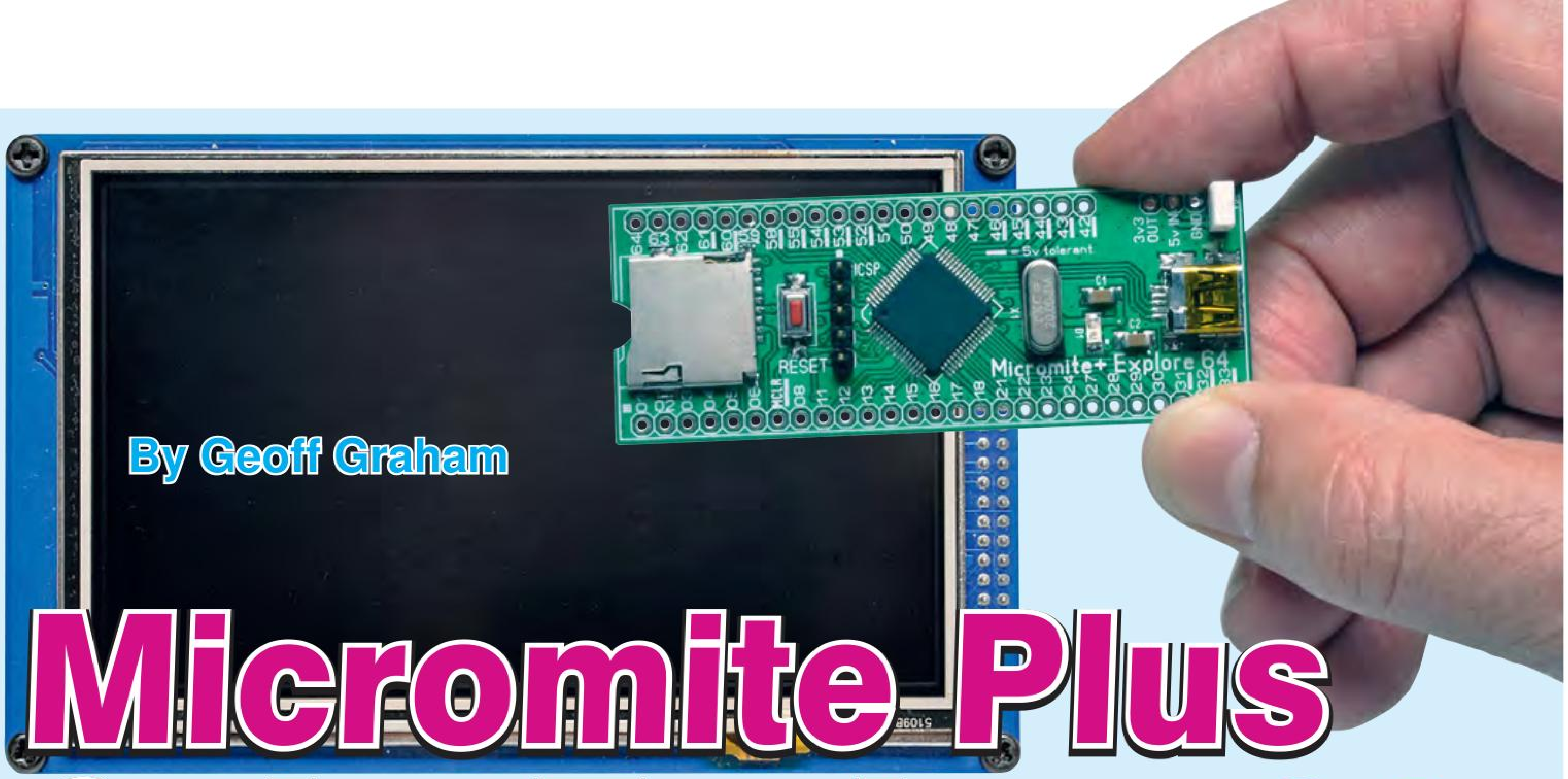
CLOSING DATE

The closing date for this offer is 31 August 2017.

April 2017 ISSUE WINNER

Mr Patrick Logue, who works at Inkoma, Northamptonshire, UK

He won a Microchip M64 Bluetooth Audio Evaluation Board, valued at £23.00



By Geoff Graham

Micromite Plus & the Explore 64

This module really packs a punch. It's more than twice as powerful as the Micromite, with much faster performance, substantially more RAM, greater program space (Flash memory), more I/O pins, support for a wide range of touchscreen displays (up to 8-inch!) and additional functions including support for USB, SD cards and a PS/2 keyboard. It can act as a sophisticated controller or as a completely self-contained computer.

THE MICROMITE PLUS is based on a PIC32 chip and is a revised version of the 28-pin and 44-pin standard Micromite described in *EPE* in the February-Apr 2017 issues. While the standard Micromite was intended for ordinary controller jobs, the Micromite Plus is much more advanced and can handle more demanding applications (such as machine controllers).

To quantify some of the improvements, the Micromite (described in Feb-Apr this year) runs at 48MHz and has 52KB of RAM and 58KB of program space, with between 19 and 33 I/O pins available depending on the version (28-pin or 44-pin). By comparison, the Micromite Plus runs at 120MHz, boasts 100KB RAM, 100KB of program space and in the version described here, has a massive 47 I/O pins available, many of them analogue-capable.

Key Improvements from the Micromite

- **2.5 times the speed**
- **92% more RAM**
- **72% more program space**
- **More I/O pins**
- **Integrated USB**
- **Supports 10 different touchscreen displays**
- **Comprehensive GUI library code**
- **Native SD card support**
- **MicroSD card socket**

The Micromite Plus can run very large programs very fast; in fact, 2.5 times as fast as the previous Micromite. It can also drive LCD touchscreens with a diagonal size of between 1.44 and 8 inches (~37-163mm), with a sophisticated graphics library. That library allows you to create animated radio buttons, numeric keypads, pushbuttons and many more GUI elements using just one line of BASIC code.

In addition, the Micromite Plus has an SD card driver and a USB 2.0 interface, giving it the capability to work as a self-contained computer.

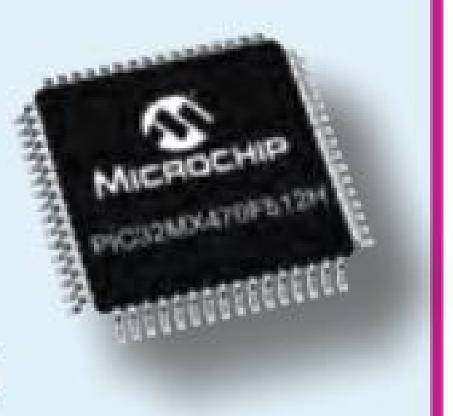
This constructional article touches on some of the new Micromite Plus software features and also describes the *Explore 64* module, designed for breadboarding. In addition to hosting the PIC32 chip running the Micromite Plus software and breaking out the I/Os, serial console and power pins, it carries an onboard USB socket, a microSD card socket, a 3.3V regulator, a reset button and an optional supply supervisor.

In coming months, we will also describe the *Explore 100*, a full Micromite Plus-based computer with display, keyboard support and SD card storage, with even more I/O pins thrown into the bargain.

Touch-sensitive LCDs

The Micromite Plus includes support for 10 different types of LCD panel, which range from a 1.44-inch module to an 8-inch panel. Note that imperial units are commonly used for LCD panels and the specified size is the diagonal measurement of the active screen area. For example, a 5-inch panel is typically around 11 × 7cm, while an 8-inch panel would be about 17 × 10.5cm.

The Micromite Plus supports displays that use both serial and parallel interfaces. There are six supported display sizes that use serial (SPI) interfaces, between 1.4 and 2.8 inches diagonal, using ILI9341, ST7735 or ILI9163 controller chips. The ILI9341



The Micromite Plus is just a standard 64 or 100-pin Microchip PIC32MX470 microcontroller programmed with the MMBasic firmware. It is this firmware that transforms the micro into an easy-to-use programmable controller that can interface with multiple devices, ranging from LCD panels to SD cards and PS/2 keyboards. Photo courtesy Microchip.

Explore 64: Main Features

- **A 32-bit CPU running at 120MHz with 512K of Flash memory and 128K RAM.**
- **Built-in BASIC interpreter is Microsoft compatible with 64-bit integer, floating point and string variables, arrays and user-defined subroutines and functions.**
- **47 input/output (I/O) pins which can be independently configured as digital inputs or outputs. 27 of these can be used as analogue inputs.**
- **The Explore 64 can be plugged into a standard solderless breadboard, or into a protoboard or a custom PCB via standard female headers.**
- **Supports touch-sensitive LCD panels ranging from 1.44 inches to 8 inches diagonal. Supports LCDs with up to 16 million colours. Built-in graphics commands include pixel, line, circle and box.**
- **Six built-in fonts plus many more fonts that can be embedded in a program.**
- **Advanced graphics commands include on-screen keyboards, buttons, switches, checkboxes and radio buttons.**
- **USB 2.0 interface which creates a serial-over-USB communications channel for program editing and upload/download from a larger computer.**
- **SD card interface supports SD cards from 4GB to 64GB capacity. Up to five files can be opened simultaneously for read, write and random access.**
- **Provision for a PS/2 keyboard so that the Explore 64 can act as a fully self-contained computer and development system.**
- **All the standard features of the Micromite range, including a comprehensive range of communications protocols, inbuilt commands to directly interface with devices such as an IR remote control and temperature sensors, PWM or SERVO outputs and special embedded controller features such as variable CPU speed, sleep, watchdog timer and automatic start and run.**
- **Power supply: 5V @ 80mA (not including LCD current drain, etc).**

is the same chip that was used in the *Micromite LCD BackPack* (introduced in May 2017) but support for the ST7735 and ILI9163 controllers is new in the Micromite Plus.

Four different displays with parallel interfaces are also supported. These range from 4.3 to 8 inches and it is with these displays that the Micromite Plus really stands out. They can display text and graphics in true 24-bit colour with a resolution of up to 800 × 480 pixels. As a result, you can display vivid photo-quality images with 16 million colours.

The parallel interface between the Micromite Plus and the display controller on the LCD panel means that your BASIC program can update the display very quickly, even though it is addressing almost half a million pixels in full 24-bit colour. This sort of performance is important when you are displaying intricate graphic objects such as radio buttons, check boxes and virtual keypads.

GUI commands

The Micromite Plus has all the BASIC graphics commands supported by the standard Micromite (for example, **PIXEL**, **LINE**, **BOX**, **CIRCLE**). But it also has a range of GUI (graphical user interface) commands that are both powerful and easy to use.

For example, by using a GUI command, you can define a check-box on the screen. When this is touched, it will be checked with a cross and when touched a second time it will be unchecked. This checking and unchecking is handled in the background (by the MMBasic interpreter) without involving the main BASIC program.

Another example is the text box. This is an on-screen box which, when touched, will display a full alphanumeric keyboard, allowing text to be entered and edited via the touch-sensitive screen.

These are two examples of the controls built into MMBasic and the range is extensive. Included are radio buttons, switches, pushbuttons, multicolour LEDs, numeric keypads and spin boxes.

MMBasic handles all the drawing, animation and interface requirements for GUI elements. All that the BASIC program needs to do is define the on-screen control (with a single command) and from then on, MMBasic does the rest. The BASIC program flow is unaffected by this activity and can later inspect the state of the control using a single function.

Fig.1 shows an example of a complex pump control panel that is constructed from GUI commands. Each object on the screen required just one line of BASIC code to create it. The GUI controls will be described in detail in a later article in this series.

SD card and keyboard

The Micromite Plus includes support for SD cards with capacities up to 64GB, formatted as either FAT16 or FAT32. Programs can be loaded and saved to the SD card and up to five data files can be open at the same time from within a BASIC program. These files can be opened for reading, writing or random access. The latter provides quick access to any part of a file and is useful for storing and recalling large amounts of data.

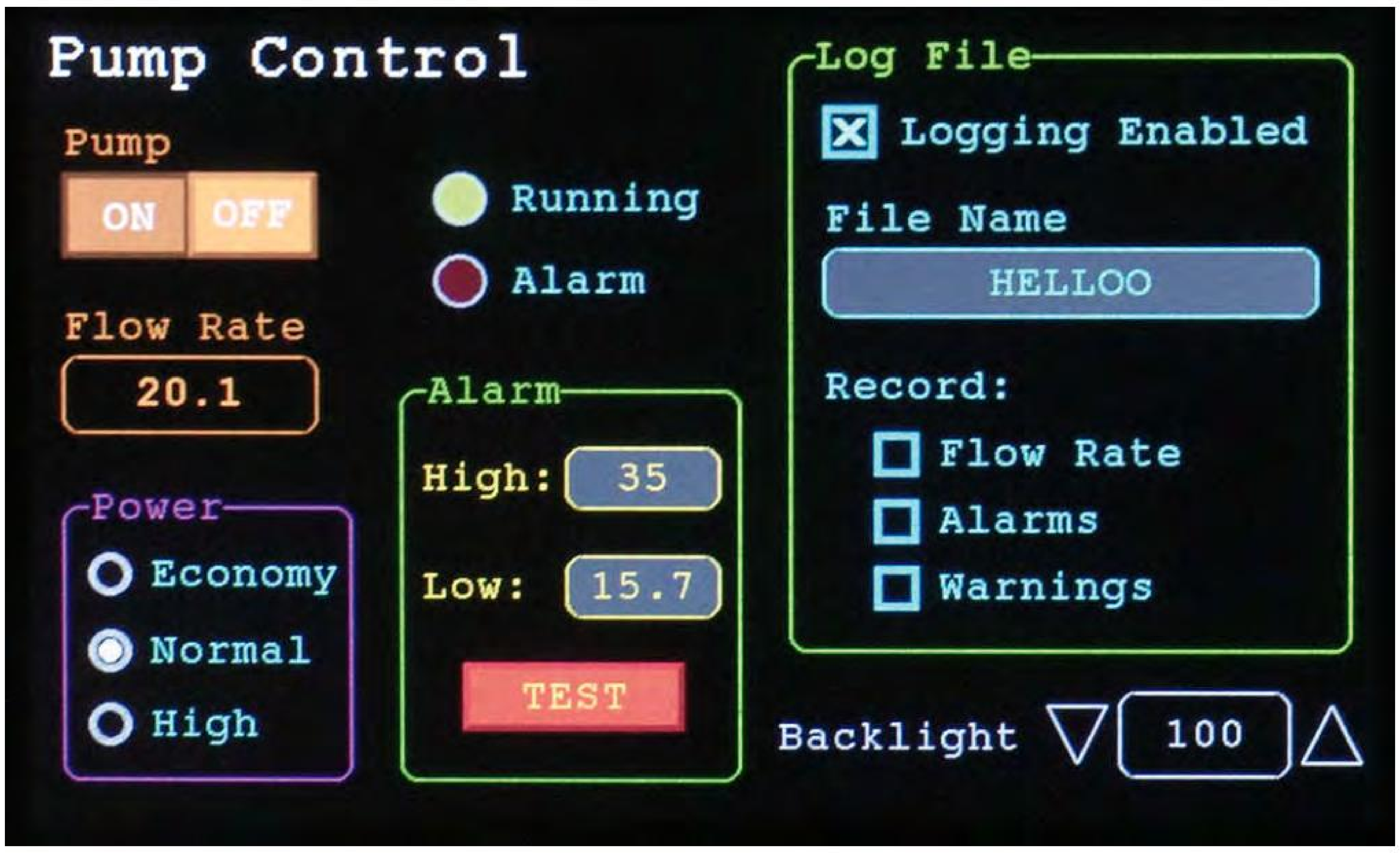
Images held on the SD card can be loaded under program control and displayed on the attached LCD to add screen logos or background images. The files created on the SD card are compatible with Windows, Linux or Macintosh systems, so data can be easily transferred from the Micromite Plus to a desktop computer for analysis.

Another important feature of the Micromite Plus is the ability to attach a PS/2 keyboard. This allows the Micromite Plus to be the heart of a fully self-contained computer, with programs composed and edited on the LCD and saved to an SD card. (This is reminiscent of the TRS-80 and Commodore 64 computers of the early 1980s.)

MMBasic includes its own colour-coded program editor, so an external computer is not required for the user to compose, edit and run their own programs on the Micromite Plus. If you wish, you can also compose and edit programs on a larger desktop or laptop computer and transfer them to the Micromite Plus using the USB interface or the serial console.

PIC32 microcontroller

The Micromite Plus firmware will run on a number of Microchip PIC32 microcontrollers with either 64 or 100 pins (see *Suitable Microcontrollers* panel). All come in surface-mount



Flow Rate 20.1

● Normal

High: 35

Low: 15.7

File Name HELLOO

Backlight 100

Fig1: this is an example of an on-screen control panel that can be created using the *Explore 64* and an LCD panel. Most objects on the screen are touch-sensitive and will react when touched. Each is created with a single BASIC command and from then on MMBasic will manage the display, including animating the objects when a user touches them. We will describe these GUI controls in detail in a later article.

TQFP packages, but their pin pitch is a relatively forgiving 0.5mm, so they can be hand-soldered to a carrier board (eg, **www.siliconchip.com.au/Shop/18/3227** and **www.siliconchip.com.au/Shop/18/3218**). Note, however, that this type of adaptor normally has pins along all four edges and so it is not suitable for plugging into a breadboard, while the *Explore 64* is breadboard friendly.

The PIC32 microcontrollers listed in the panel each have an optimised MIPS 32-bit processor core which can run at up to 120MHz and supports 512KB of Flash memory and 128KB of RAM. This might sound complex and daunting, but they are not expensive and the complexity is hidden by the MMBasic interpreter.

This month, we are presenting the *Explore 64*, which uses the 64-pin version of the chip, while a future issue will introduce the *Explore 100*, which uses the 100-pin chip and is designed to mount on the back of a 5-inch LCD panel (although it can be used standalone or with different display sizes).

Explore 64

The *Explore 64* is a small PCB designed by Graeme Rixon of Dunedin, New Zealand. It can be plugged into a solderless breadboard for prototyping and for exploring the capabilities of the Micromite Plus, but could also be used as a replaceable module that's plugged into a larger system.

The PCB includes a 64-pin PIC32 (the Micromite Plus), a mini USB connector, a microSD card socket and the power supply parts. There are 47 I/O pins. Of these, 17 are 5V tolerant and 27 can be used as analogue inputs – there's plenty of capability to develop complex projects that need lots of I/O ports.

In order to make it small enough to fit onto a breadboard, the PCB was designed using surface-mount components. Despite this, it's not difficult to build. IC1 (the microcontroller) uses a 0.5mm spacing between its pins and can be hand-soldered using a normal temperature-controlled soldering iron. In addition, the solder pads for the passive components will accept either 1206 or 0805-size components, so you can use whatever size suits your soldering skills.

Circuit details

Fig.2 shows the circuit details of the *Explore 64*. It's designed to run from a 5V supply and this can be fed in via USB socket CON1, if jumper JP1 is fitted. Alternatively, if JP1 is removed, the 5V supply can be fed in via the 5V IN and GND pins on the board's edge.

The 5V supply is reduced to 3.3V by low-dropout linear regulator REG1, an MCP1703A. The resulting +3.3V rail is then used to power microcontroller IC1 and is also made available on an I/O pin on the board's edge for powering external circuitry.

The capacitors across the supply lines before and after the regulator ensure regulator stability and reduce variations in supply voltage with changing current demands. Note the capacitor connected between pin 56 of IC1 and ground. This stabilises IC1's internal 1.8V core regulator and must be a multilayer ceramic type, preferably with an X5R or X7R dielectric.

Ideally, all capacitors should be X5R or X7R ceramic types except for the 22pF crystal load capacitors, which should be C0G/NP0 ceramic. As a bonus, these capacitors tend to have a very long life (practically indefinite).

I/O pins

Most of IC1's I/O pins are connected to pads along the sides of the PCB, as depicted on either side of the circuit diagram and in Table 1, along with pads for the +5V and +3.3V supply rails and ground. CON3 is the microSD card connector. The I/O pins used for this connector are also brought out to the sides of the PCB so that they can be used as general purpose I/O pins if the microSD connector isn't used.

IC2 (bottom left of Fig.2) is an optional 'supervisor' chip. This holds the Micromite Plus in reset until the 3.3V power supply reaches a set level (2.7V in this case). It will also monitor the 3.3V line and reset the microcontroller if there is a glitch or if the supply drops to a low value (a brown-out condition). IC1 has an internal brown-out detector, but its threshold is much lower and external circuitry could stop working well before this trips.

The supervisor chip will be important if the Micromite Plus is used in an industrial situation where power fluctuations and electrical noise are common. In other situations, the supervisor chip is not critical and so IC2 and its associated 100nF capacitor can be left out with no ill-effects.

CON2 is an in-circuit serial programming (ICSP) header and this allows the Micromite Plus firmware to be loaded into a blank microcontroller. It suits a Microchip PICkit 3 programmer or similar.

The only other items of note are the USB socket, which connects directly to IC1, and a 20MHz crystal which is used as the clock source for IC1. SB1 is a solder bridge which should be left open; it's included to give the option of supporting a USB device (such as a USB keyboard) in a future firmware upgrade.

Construction

Building the *Explore 64* is reasonably easy despite the fact that it uses SMD components. Soldering SMD devices is not that much harder than soldering through-hole components; it just requires a different technique and is easy when you have mastered it.

The essential tools are a good magnifier, plenty of flux and a steady hand. The magnifier needs to be at least ×3 power and preferably ×10. A jeweller's loupe can be used, but the best option is a stereo microscope.

The flux should be a good quality flux paste/gel such as Cat. H1650A from Altronics or Cat. NS3036 from Jaycar.

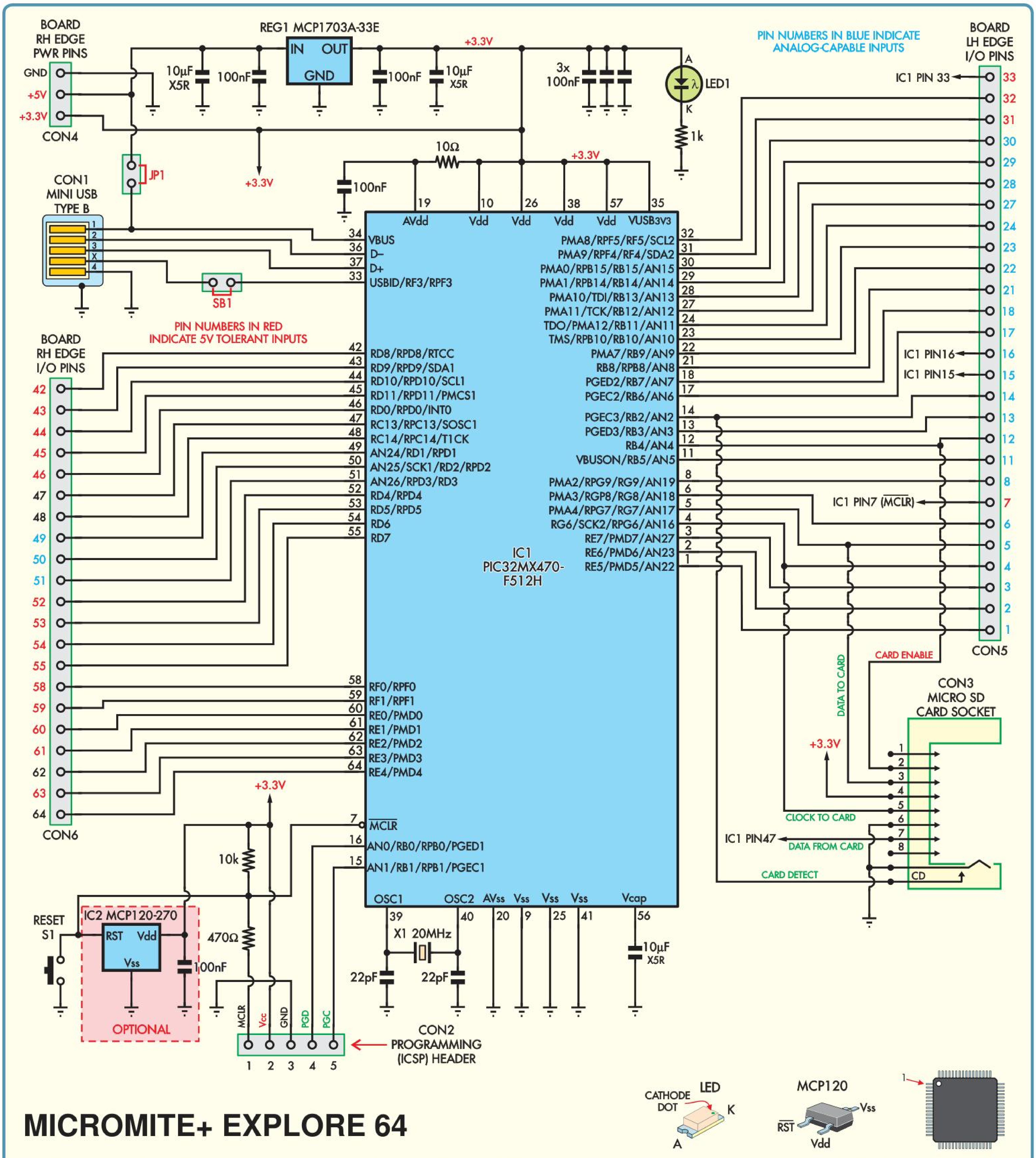

MICROMITE+ EXPLORE 64
BOARD RH EDGE PWR PINS
GND
+5V
+3.3V
CON4
REG1 MCP1703A-33E
IN
OUT
GND
10µF X5R
100nF
+3.3V
3x 100nF
A
LED1
K
1k
PIN NUMBERS IN BLUE INDICATE ANALOG-CAPABLE INPUTS
BOARD LH EDGE I/O PINS
IC1 PIN 33
JP1
+3.3V
10Ω
CON1 MINI USB TYPE B
SB1
PIN NUMBERS IN RED INDICATE 5V TOLERANT INPUTS
BOARD RH EDGE I/O PINS
AVdd
Vdd
VUSB3V3
VBUS
D–
D+
USBID/RF3/RPF3
PMA8/RPF5/RF5/SCL2
PMA9/RPF4/RF4/SDA2
PMA0/RPB15/RB15/AN15
PMA1/RPB14/RB14/AN14
PMA10/TDI/RB13/AN13
PMA11/TCK/RB12/AN12
TDO/PMA12/RB11/AN11
TMS/RPB10/RB10/AN10
PMA7/RB9/AN9
RB8/RPB8/AN8
PGED2/RB7/AN7
PGEC2/RB6/AN6
PGEC3/RB2/AN2
PGED3/RB3/AN3
RB4/AN4
VBUSON/RB5/AN5
PMA2/RPG9/RG9/AN19
PMA3/RGP8/RG8/AN18
PMA4/RPG7/RG7/AN17
RG6/SCK2/RPG6/AN16
RE7/PMD7/AN27
RE6/PMD6/AN23
RE5/PMD5/AN22
RD8/RPD8/RTCC
RD9/RPD9/SDA1
RD10/RPD10/SCL1
RD11/RPD11/PMCS1
RD0/RPD0/INT0
RC13/RPC13/SOSC1
RC14/RPC14/T1CK
AN24/RD1/RPD1
AN25/SCK1/RD2/RPD2
AN26/RPD3/RD3
RD4/RPD4
RD5/RPD5
RD6
RD7
IC1 PIC32MX470-F512H
RF0/RPF0
RF1/RPF1
RE0/PMD0
RE1/PMD1
RE2/PMD2
RE3/PMD3
RE4/PMD4
MCLR
AN0/RB0/RPB0/PGED1
AN1/RB1/RPB1/PGEC1
OSC1
OSC2
AVss
Vss
Vcap
CON6
IC1 PIN16
IC1 PIN15
IC1 PIN7 (MCLR)
CON5
CARD ENABLE
DATA TO CARD
CON3 MICRO SD CARD SOCKET
CLOCK TO CARD
IC1 PIN47
DATA FROM CARD
CARD DETECT
CD
10k
470Ω
RESET S1
IC2 MCP120-270
RST
Vdd
Vss
100nF
OPTIONAL
X1 20MHz
22pF
22pF
10µF X5R
MCLR
Vcc
GND
PGD
PGC
CON2 PROGRAMMING (ICSP) HEADER
LED
CATHODE DOT
K
A
MCP120
Vss
RST
Vdd
1

Fig.2: the *Explore 64* is mostly a carrier for the 64-pin Micromite Plus (IC1), so its circuit is relatively simple. Most I/O pins from the microcontroller are made available on the board's edge where they can be plugged into a solderless breadboard or into header sockets on a larger board. Voltage regulator REG1 provides 3.3V for the microcontroller and the reset supervisor (IC2) ensures that the microcontroller is held in reset if the 3.3V supply drops below a critical level.

Fig.3 shows the parts layout on the *Explore 64* PCB. The first step is to install microcontroller IC1. Apply flux to all of its pads, then position the chip so that its pin 1 (marked with a dimple) is lined up with the pin 1 marking on the PCB (at left). That done, hold it in position using a toothpick or tweezers and solder one corner pin.

Now check that the IC is correctly aligned; if not, re-melt the solder while gently nudging it into position. Once it's in position, apply more flux to all the pins and solder each one in turn, then recheck the first pin and add fresh solder if necessary.

The technique here is simple; put a very small amount of solder on your iron's tip, touch the tip to the solder pad and slide it forwards to gently touch the first pin. The solder should flow around the pin and the pad. You should then be able to solder at least 15 more pins (one side of the IC) before you need to add more solder to the iron.

The secret is to be generous with the flux, as this will allow the solder to flow freely onto the pads and their corresponding pins. Alternatively, if you have a mini-wave tip or a very steady hand, with sufficient flux in place, you can drag solder across one side (16 pins) in a single movement.

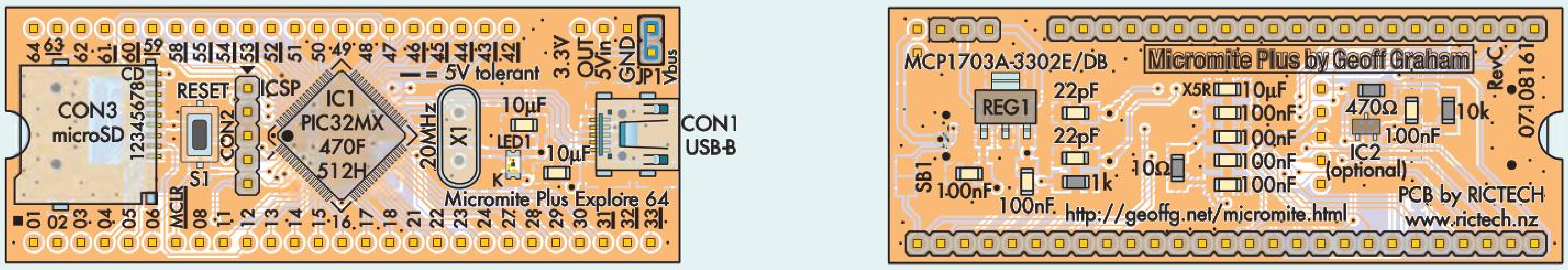
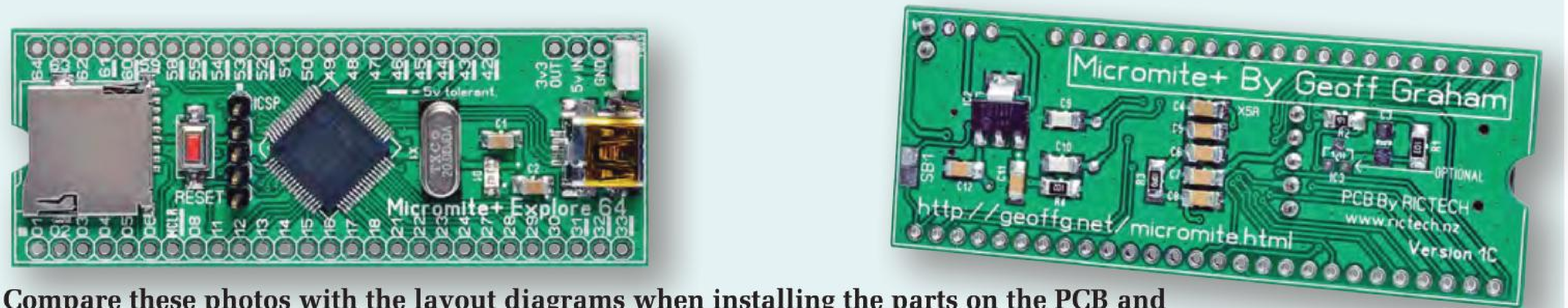

CON3
microSD
RESET
ICSP
CON2
S1
MCLR
IC1
PIC32MX
470F
512H
20MHz
X1
10µF
LED1
K
10µF
= 5V tolerant
3.3V
OUT
5Vin
GND
JP1
Vbus
CON1
USB-B
Micromite Plus Explore 64
MCP1703A-3302E/DB
REG1
22pF
22pF
X5R
10µF
100nF
100nF
100nF
100nF
100nF
100nF
470Ω
10k
IC2
(optional)
1k
10Ω
SB1
Micromite Plus by Geoff Graham
RevC
07108161
PCB by RICTECH
www.rictech.nz
http://geoffg.net/micromite.html

Fig.3: follow these top and bottom PCB parts layout diagrams to build the *Explore 64*. The top of the PCB (left) carries most of the parts including the microcontroller, SD card socket and USB connector, while most of the power supply components and I/O pin headers are on the bottom side.


ICSP
RESET
5V tolerant
3v3
OUT
5V IN
GND
Micromite+ Explore 64
Micromite+ By Geoff Graham
X5R
OPTIONAL
PCB By RICTECH
www.rictech.nz
http://geoffg.net/micromite.html
Version 1C

Compare these photos with the layout diagrams when installing the parts on the PCB and check that all polarised parts are correctly orientated. CON1-CON3, IC2 and S1 can be left off if they are not required but most constructors will want to fit them.

Often you will find that you are actually soldering two or more pins simultaneously, but the solder will not usually bridge the pins. If it does, this is an indication that you have too much solder on your iron. If any pins are bridged, come back later with solder wick (and more flux) and remove the excess.

The SD card socket is next on the list. It's located on the PCB by two small plastic pins that match two holes on the board. Solder its four mounting lugs first, followed by the signal pins. These pins are soldered using the same technique as for IC1.

Note that the SD card connector's pins are fragile and the plastic they are embedded in will melt if too much heat is applied. Touch the soldering iron to the pins for a very short time. As before, apply plenty of flux before soldering.

The mini-USB connector can now go in. It also has locating pins to position it correctly and you should push it down firmly so that it sits flush against the board. Once again, solder the mounting lugs first and then the signal pins. These are a bit of a challenge as they are partially under the connector's body and you will need a fine-tipped soldering bit to reach them; we have extended the pads outside the body to make this easier.

Passive SMD components

Soldering the passive SMD components requires a different technique compared to that used the microcontroller. Start by applying flux to one solder pad and then tin it by applying a thin layer of solder to it. That done, you have two choices.

First, you can place the component in position and hold it still with a toothpick or tweezers while you apply the iron's tip to the end sitting on the tinned pad, so that the component's lead sinks into the solder underneath. Alternatively, you can slide the component into place while heating the solder on the pad. The second technique will probably require more practice, but it will be quicker once you get used to it. Either way, once the component is secure, apply more flux and solder the other end before returning to the first to make sure that the joint is good. Once again, the secret is to use plenty of flux and don't forget that it may have boiled off one of the pads while you were soldering the other end of the component, so keep reapplying it.

LED1 (the power indicator LED) is polarised and should be marked with a bar or dot on the cathode end. Some LEDs might be different so it's good practice to use a multimeter's diode test facility to check the polarity. Be sure to solder it in with its cathode towards the bottom of the board, as shown in Fig.3.

You can use a similar technique as used for the passives to solder regulator REG1 and IC2 (if this is to be fitted). The only trick is that with REG1, you first apply flux to all four pads and then start by soldering one of the smaller leads. That done, check its alignment before soldering the other smaller leads and finally the large tab. It may take a few seconds to heat the part and PCB up enough to get a good solder joint on that tab.

Crystal X1 is a through-hole part and can be soldered using the usual method. The PCBs supplied will a have solder mask over the top side of the mounting pads so it should be possible to push the crystal can right down onto the PCB surface before soldering it.

That just leaves tactile pushbutton S1 (which can be fitted either way around) and the various pin headers, which are made by snapping longer pin headers to length and then

Suitable microcontrollers

The Micromite Plus uses Microchip's MX470 series chips. These are part of Microchip's PIC32 (32-bit processor) range and are available in 64-pin and 100-pin packages with speeds of 100MHz or 120MHz.

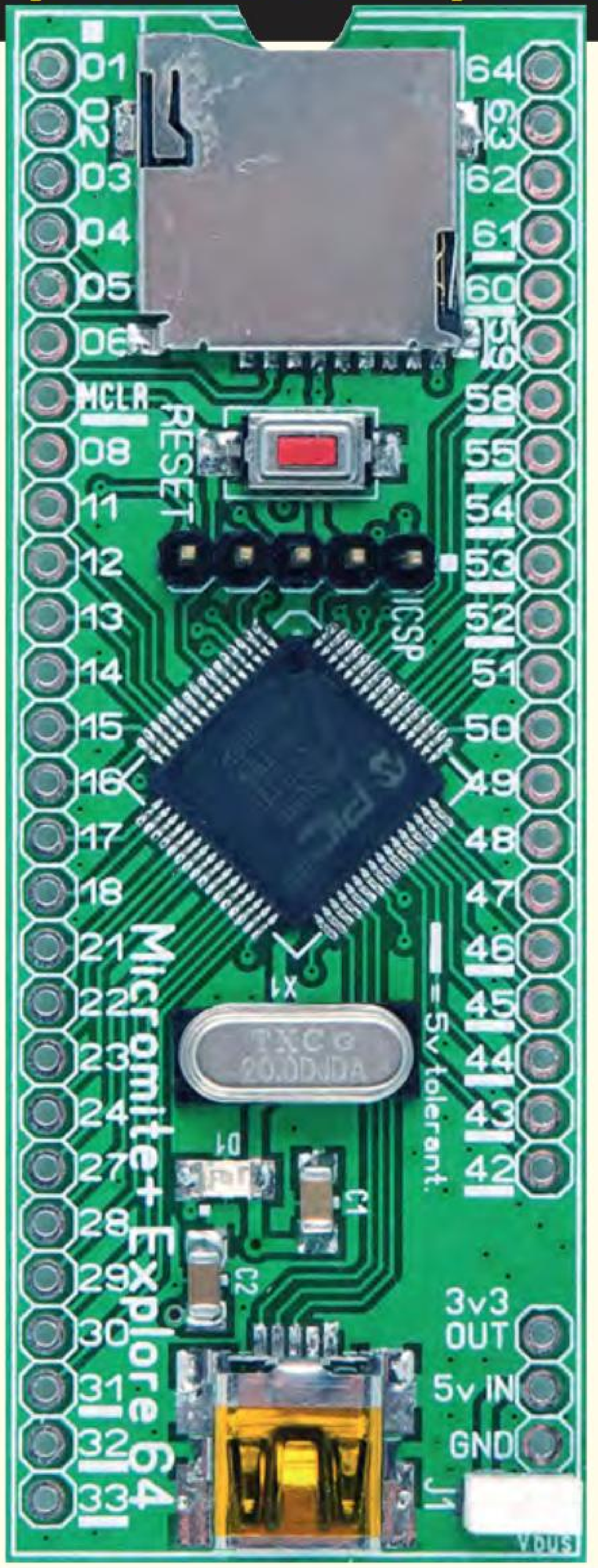
The Micromite's firmware starts up at 100MHz so you can use chips with either speed. However, a 120MHz version gives you the option of stepping up to 120MHz in your program.

The recommended chips for the Micromite Plus are:

- **PIC32MX470F512H-I/PT: 64-pin, 100MHz**
- **PIC32MX470F512H-120/PT: 64-pin, 120MHz**
- **PIC32MX470F512L-I/PF: 100-pin, 100MHz**
- **PIC32MX470F512L-120/PF: 100-pin, 120MHz**

micromite.org will supply the 120MHz version in all cases, ie, for individually purchased programmed PICs as well as in kits.

Table 1: Explore-64 I/O pin allocations



SSD1963 D5 - ANA	1	64	ANA - SSD1963 D4
SSD1963 D6 - ANA	2	63	5V - SSD1963 D3 - PWM1C
SSD1963 D7 - ANA	3	62	ANA - SSD1963 D2
SPI2 CLOCK - ANA	4	61	5V – SSD1963 D1
SPI2 OUT - ANA	5	60	5V – SSD1963 D0
CONSOLE Rx	6	59	5V – COM1 Rx
CPU Reset when Low		58	CONSOLE Tx
SPI1 OUT - ANA	8	55	5V - KEYBOARD DATA
COM2 Tx - ANA	11	54	5V - KEYBOARD CLOCK
ANA	12	53	5V - PWM 2A
COM2 Rx - ANA	13	52	5V - COUNT
ANA	14	51	ANA - COUNT - WU - IR
COM1 Tx - ANA	15	50	ANA - SPI1 CLOCK
COM3 Tx - ANA	16	49	ANA - COUNT
COM3 Rx - ANA	17	48	PWM 1A
ANA	18	47	SPI2 IN - PWM 2B
ANA	21	46	5V
ANA	22	45	5V - SPI1 IN
COUNT - ANA	23	44	5V - I^{2}C CLOCK
SSD1963 WR - ANA	24	43	5V - I^{2}C DATA
SSD1963 RS - ANA	27	42	5V - PWM 1B
SSD1963 Reset - ANA	28		
COM1 Enable - ANA	29		
ANA	30		3.3V OUTPUT (100mA MAX)
5V	31		5V OUTPUT OR INPUT
5V	32		GROUND
DIGITAL INPUT ONLY	33		

(1) Pin number refers to the number used in MMBasic to identify an I/O pin; **(2)** All pins (except 33) are capable of digital input/output and can be used as an interrupt pin; **(3)** ANA means that the pin can be used as an analog input; **(4)** 5V means that the pin is 5V tolerant; **(5)** COUNT means that the pin can be used for counting or frequency/period measurement; **(6)** SSD1963 refers to pins that are used to interface to LCD panels using the SSD1963 controller; **(7)** If the serial console is disabled the CONSOLE pins (6 and 58) can be used for COM4

Note: the Explore 64 is shown here scaled up by a factor of almost 2.

soldering them in the usual manner. Normally, JP1 and CON2 should be fitted on the top of the board, with the other pin headers on the bottom (see Fig.3). CON2 does not need to be fitted if you have a pre-programmed PIC chip.

Loading firmware into the PIC32

Pre-programmed PIC32s are available from the **micromite.org** online shop. If using a blank PIC32 chip, you will need to program it yourself. In this case, you will need a suitable programmer such as a PICkit 3 from Microchip.

The *Explore 64* has a set of header pins on the top surface labelled ICSP and the PICkit 3 plugs directly onto them (see photo at left).

The first step is to download the firmware from the *EPE* website and extract the Micromite Plus HEX file (Micromite_Plus_V5.04.04.hex). It's then just a matter of using your computer and the MPLAB software supplied with the PICkit 3 (or downloaded from Microchip) to program the HEX file into the microcontroller (see page 18 of the May 2017 issue for further details).

Serial console

To set up and use the *Explore 64*, you must connect a terminal emulator to its console. The console is a serial interface over which you can issue commands to MMBasic to configure the chip and edit or run programs. MMBasic also uses the console to display error messages.

The *Explore 64* actually has two consoles, one serial and one USB. The USB console is useful for making quick changes to a running program or for developing a program where the *Explore 64* is being used as a general-purpose computer. However, if you are using the *Explore 64* as a controller, it's best to use the hard-wired serial console via a USB-to-serial converter.

The reason for this is that when the Micromite Plus PIC32 is reset, it will also reset its USB interface. This generally means that you must close the terminal emulator, then restart it to restore the connection. When you are developing a program for controlling other equipment, you often need to reset the Micromite Plus and repeatedly closing and re-opening the terminal emulator can get tedious.

A USB-to-serial converter is required in order to use the hard-wired serial console. One end of this converter plugs into a USB port on your computer, while the other end connects to the *Explore 64's* serial console (Fig.4). To your computer it will look like a serial port (via USB), while the connection to the *Explore 64* is a standard serial interface with TTL (0-3.3V) signals levels.

We recommend converters based on

A Microchip PICkit 3 can be used to load the firmware into the PIC32 micro. Alternatively, you can buy a pre-programmed PIC32 chip – both available from micromite.org.

the CP2102 chip or our own design (These are available from the **micromite.org** online shop at: **http://micromite.org/shop/development-tools/usb-to-serial-module/**). Our version is a high-quality, plug-and-play alternative to the CP2102 module. *Fully compatible with ALL MicroMites*.

Fig.4 shows how a CP2102-based converter is connected to the *Explore 64* (other types should be similar). Note that the converter feeds through the 5V supply rail derived from the PC's USB port to power the *Explore 64*.

When the converter is plugged into your computer and the correct driver is installed, it will appear as a serial port (eg, COM3 in Windows). You then need to start a terminal emulator on your computer.

For Windows, we recommend **Tera Term V4.88** which can be downloaded for free from **http://tera-term.en.lo4d.com** You will need to set its interface speed to 38,400 baud and connect it to the serial port created by the USB-to-serial converter. Once that's been done, hit the Enter key in the terminal emulator and you should see the Micromite's command prompt (>). You can then enter, edit and run programs from this command prompt using nothing more than the PC's terminal emulator and the USB cable.

Testing

If you don't see the Micromite's prompt, something is definitely wrong and you will need to go through the following troubleshooting procedure.

The first step is to measure the current drawn by the *Explore 64* from the 5V power supply. With nothing attached to its I/O pins, this should be 60-80mA. If it's substantially more or less than this, it indicates that something is wrong with either the soldering, the microcontroller or its power supply.

If this is the case, check that +3.3V is present on pins 10, 26, 38, 57 and 35 of IC1 and on various other components – see Fig.2. If this checks out, check that the capacitor connected to pin 56 (Vcap) of IC1 is correctly soldered and is the correct type; it must be a 10µF multi-layer ceramic type. A faulty capacitor will prevent the internal CPU from running and the current drain will be quite low (less than 10mA).

A disconnected pin can also prevent the micro from running, so check the soldering on IC1's pins. It's easy to miss a pin and leave it floating just above its solder pad and without a decent magnifier and bright light, this may not be obvious.

Another cause of low current drain is either not programming the Micromite Plus firmware into the PIC32 chip or ignoring an error during this operation. Check that the micro has been correctly programmed.

If the current drain is about right, the next step is to attach the *Explore 64's* console to your computer or terminal emulator as shown in Fig.4. You could also try using the USB connector as the console, but this is best left until last as it can involve some work in installing the correct device driver and that would just confuse the testing process.

With the console connected, press the Reset button on the *Explore 64* and you should see the start-up banner as shown in Fig.5. Note that you will not see this banner if you are using the USB console because resetting the Micromite Plus will also reset the USB interface.

If you don't see the start-up banner you should check the console Tx pin for some activity when the Reset button is pressed (this indicates that MMBasic is outputting its start-up banner). This can be done using a logic probe, oscilloscope or, at a pinch, a moving coil multimeter. If you do see some activity, the fault is probably either an incorrect console connection or is in the USB-to-serial converter.

User manuals

The Micromite Plus is quite an advanced device. After all, it is a full computer with a multitude of facilities. As a result, it has two user manuals which together add up to almost 150 pages.

The first manual is called the *Micromite User Manual* and it describes the features that are standard across the whole Micromite range, from the original 28-pin version to the 100-pin Micromite Plus (to be described in this magazine in the near future). The extra features of the Micromite Plus are described in the *Micromite Plus Addendum* which covers subjects such as the GUI functions, the SD card interface and other features that are only found in the Micromite Plus.

Both manuals are in PDF format and available for free download from the *EPE* website. Before you build and test the *Explore 64*, it would be worthwhile downloading and looking through them as they provide a lot more information than we can fit into these pages.

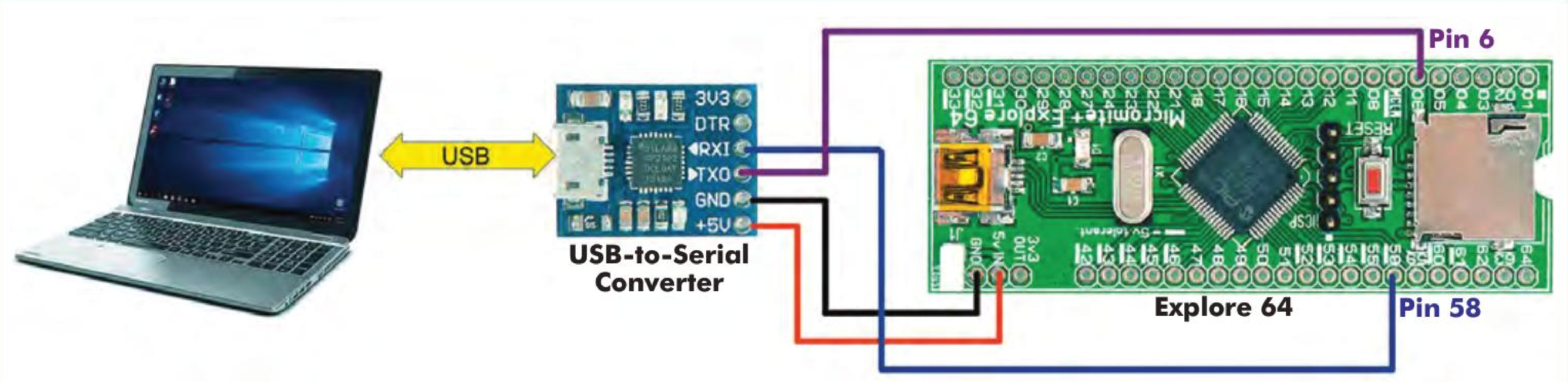
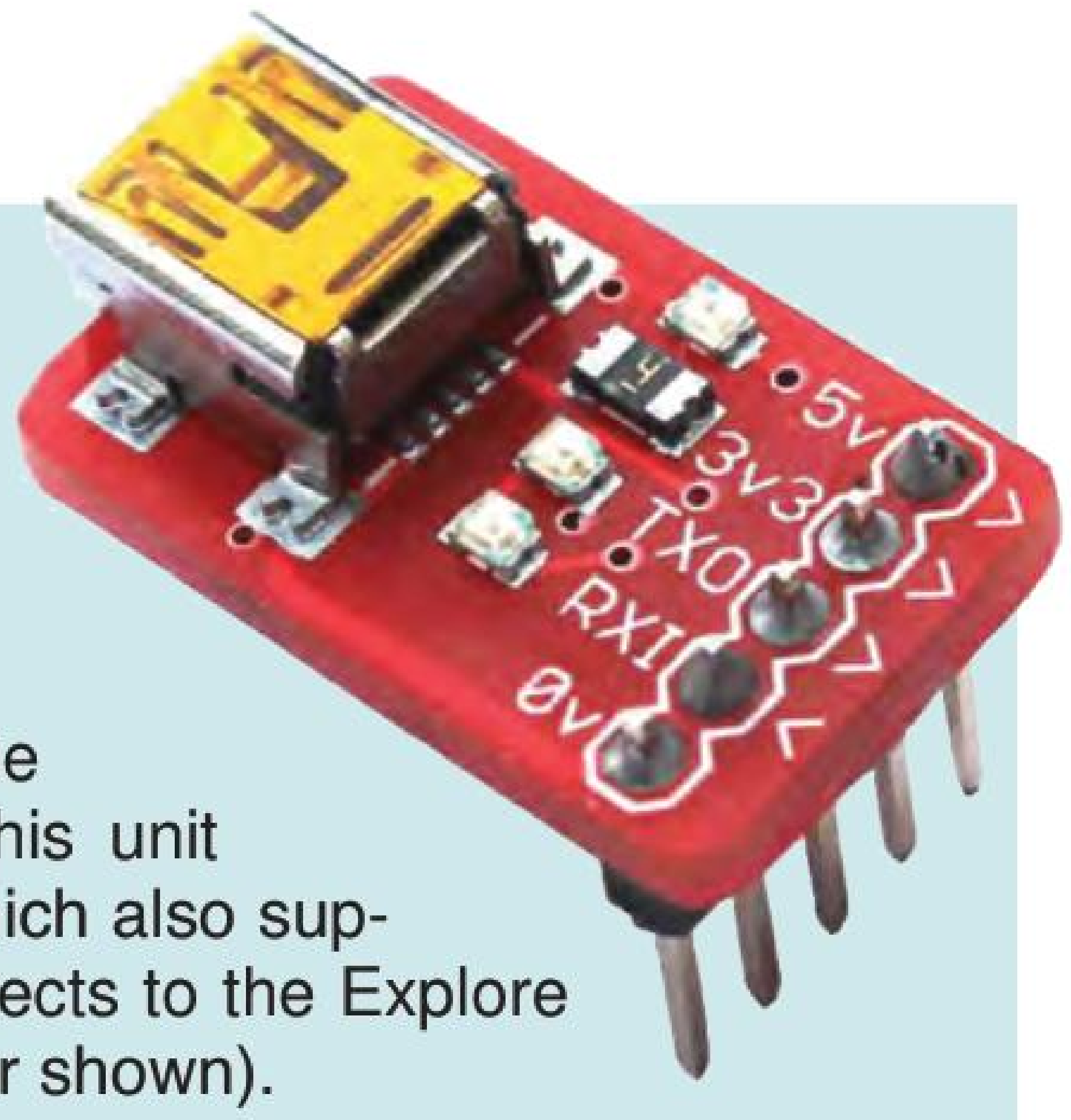
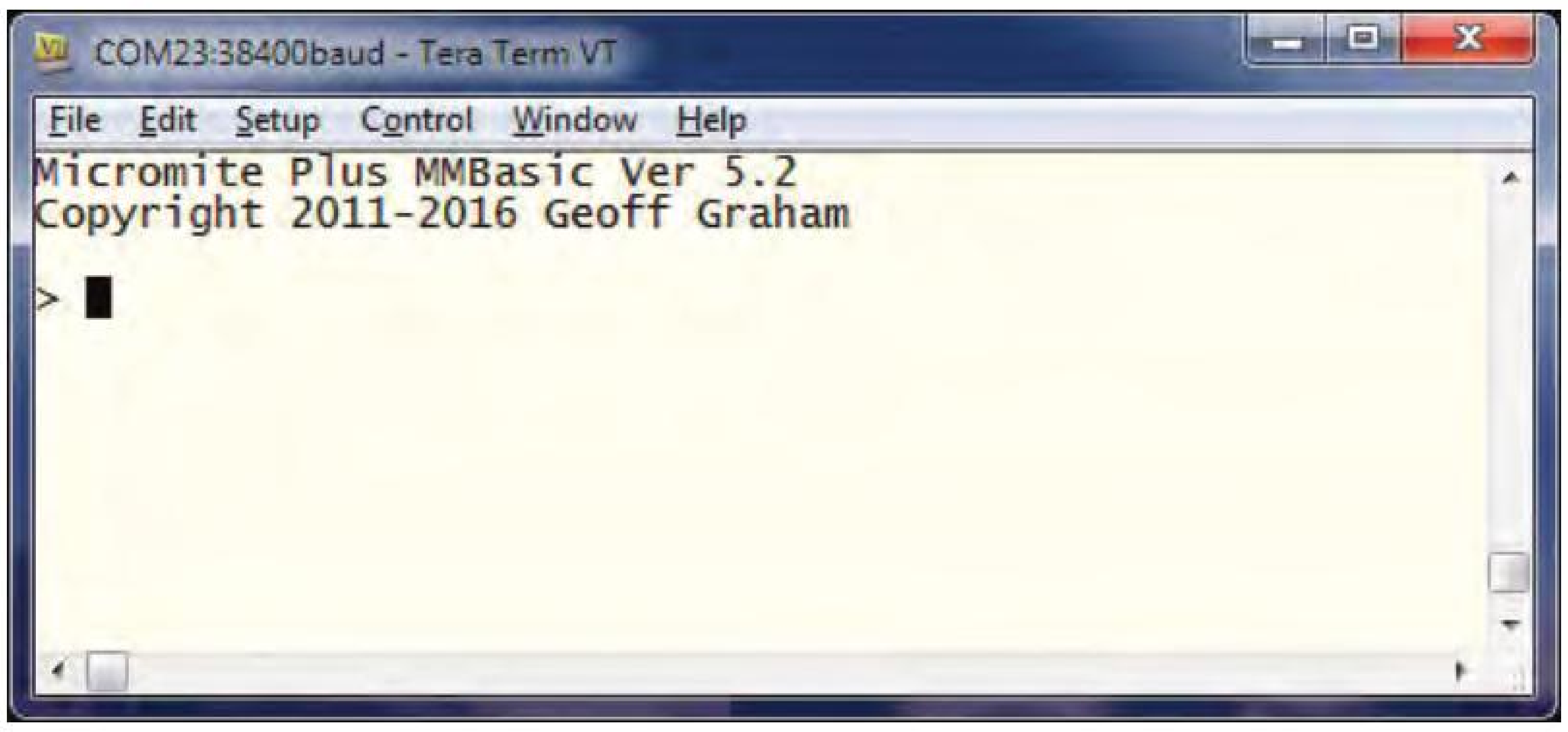


Fig.4: here's how to connect a USB-to-serial converter between your PC and the *Explore 64*. Note that the converter can supply the 5V power required by the *Explore 64* but you also need to ensure you remove jumper JP1 (see text).

USB-to-serial converter



A USB-to-serial converter such as this unit from the **micromite.org** is necessary in order to use the serial console when developing or editing programs. This unit plugs directly into your PC's USB port (which also supplies the power). The convertor then connects to the Explore 64, as shown in Fig.4 (alternative convertor shown).



```
Micromite Plus MMBasic Ver 5.2
Copyright 2011-2016 Geoff Graham

> 
```

Fig.5: this is what you should see in your terminal emulator when you press the reset button on the *Explore 64*. If you don't see this, the probable reason is that the USB-serial converter is not connected correctly.

Configuring an SD card

Once your *Explore 64* is up and running, you can configure it to use an SD card. This occupies I/O pins 4, 5, 12, 14 and 47, in other words, they can no longer be used as general purpose I/Os (GPIOs).

To set up the SD card, you need to use the **OPTION SDCARD** command. Note that this must be entered at the command prompt and cannot be used in a program. The syntax is:

OPTION SDCARD CS-pin, CD-pin

where 'CS-pin' is the I/O pin number that is used as chip select and 'CD-pin' is the I/O pin number used for the card detect pin on the SD card connector.

This command only needs to be run once. When the Micromite is restarted, MMBasic will automatically initialise the SD card interface. If the SD card is no longer required, then use the following command:

OPTION SDCARD DISABLE

This will disable the SD card and return the I/O pins for general use.

On the *Explore 64*, the SD card Chip Select (CS) signal is on pin 12 and the Card Detect (CD) signal is on pin 14. So, to enable the SD card you should enter the following command:

OPTION SDCARD 12, 14

To verify the configuration, you can use the command **OPTION LIST** to list all options that have been set, including the configuration of the SD card. As another test, you can pop an SD card into the slot and run the command **FILES**. This will list all the files and directories on the SD card.

Note that some SD cards can be temperamental and may not work so if you encounter a problem here, try a few SD cards before deciding that you have a fault. For example, some cards (especially high capacity, fast types) may demand more current than the power supply on the *Explore 64* can provide.

USB interface

The USB interface on the *Explore 64* doesn't need configuring. MMBasic monitors the interface and if it detects a host computer, it automatically configures it for serial emulation over USB.

A Windows-based host computer (versions before Windows 10) will require the installation of the 'SILICON CHIP Serial Port Driver', which can be downloaded from the *EPE* website. Macintosh and Linux-based computers do not need a device driver, as support is built into the operating system. Similarly, Windows 10 should not require any drivers to be installed.

Once configured, the USB interface works just like a serial port that's connected to the console. You can start up a terminal emulator such as 'Tera Term for Windows' and tell it to connect to the virtual serial port created by the Micromite Plus.

Anything outputted by the Micromite Plus will be sent out on both the USB interface and the serial console. Similarly, anything received on either of these interfaces will be sent to MMBasic.

One benefit of using the USB interface as the console is that you can disable the serial console. This allows you to use the I/O pins allocated to the serial console for other duties, including use as a fourth serial I/O port. This is described further in the *Micromite Plus Addendum*.

Explore 64 Parts List

Where to buy parts

IMPORTANT – See the box at the end of the article!

1 double-sided PCB from micromite.org 72 × 27mm
1 tactile switch, 2-pin, surface-mount (S1)
1 20MHz crystal, low profile HC-49 (X1)
1 Mini USB type B socket (CON1) (Altronics P1308 or similar)
1 microSD card socket (CON3) (Altronics P5717 or similar)
2 40-pin or 50-pin male headers, 2.54mm pitch (JP1, CON2, CON4-6)
1 shorting block (JP1)

Semiconductors

1 PIC32MX470F512H-120/PT (120MHz) or PIC32MX470-F512H-I/PT (100MHz) 32-bit microcontroller programmed with Micromite_Plus_V5.04.04.hex (IC1)
1 MCP1703A(T)-3302E/DB low-dropout 3.3V regulator, SOT-223 (REG1)
1 MCP120(T)-270I/TT 2.7V supply supervisor, SOT-23 (IC2; optional – see text)
1 green SMD LED* (LED1)

Capacitors*

3 10µF 6.3V ceramic, X5R or X7R
7 100nF 50V ceramic, X5R or X7R
2 22pF ceramic, C0G/NP0

Resistors, 1% or 5%*

1 10kΩ 1 470Ω 1 1kΩ 1 10Ω

* Use SMD 3216 (1206 imperial) size; 2012/0805 or 1608/0603 sizes are also suitable but not recommended for beginners.

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Configuring a display

As stated, MMBasic for the Micromite Plus has inbuilt support for 10 different LCD panels (1.44 to 8 inches). The smaller displays employ an SPI interface which uses only five I/O pins, so they are a good choice when you need a small display and want to keep as many I/O pins free as possible.

By contrast, the larger displays (4.3-8 inches) use an 8-bit parallel interface to transfer data. This requires 11 I/O pins, but this is a small sacrifice considering the speed that it brings.

Supported LCD panels

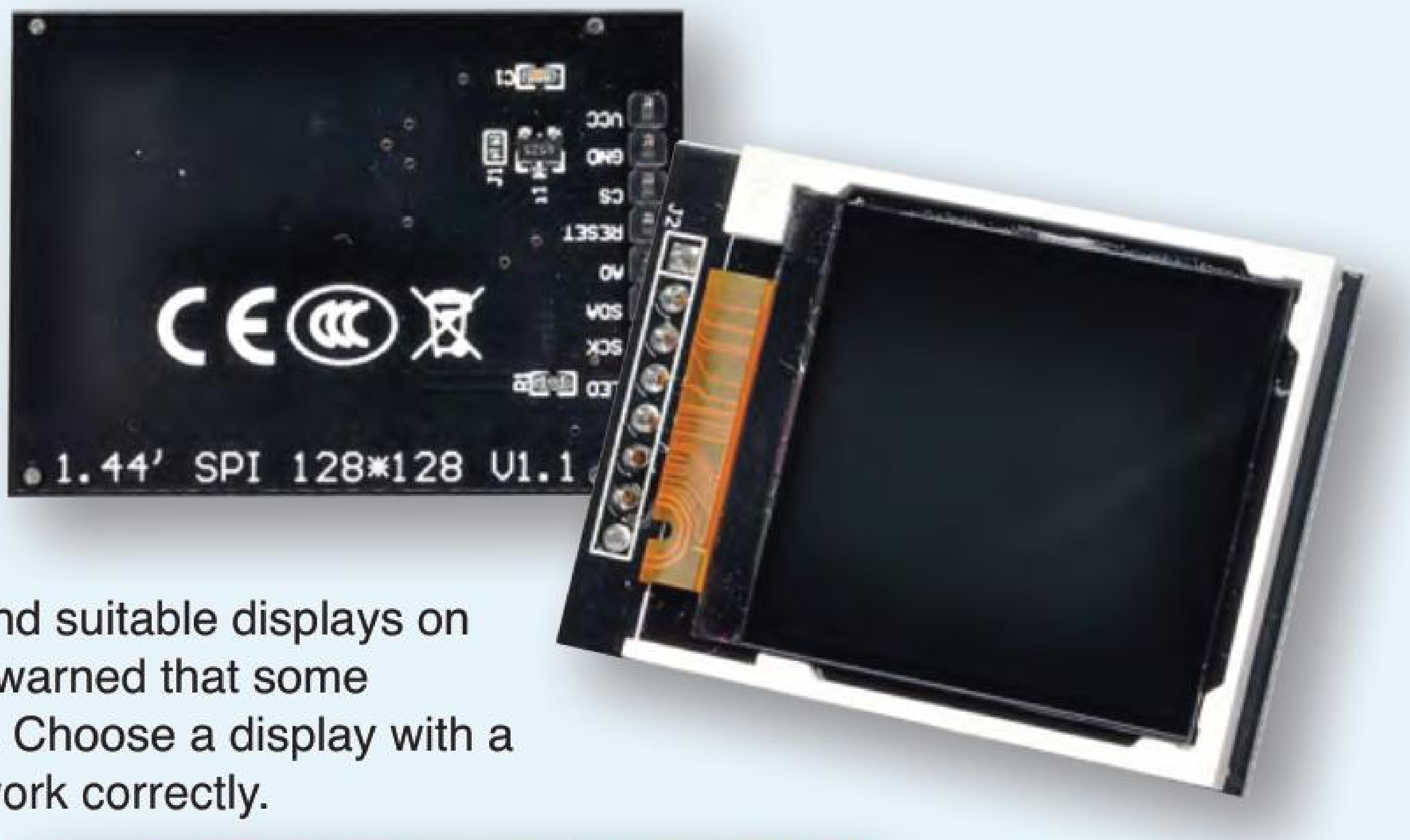
The Micromite Plus has built-in support for 10 different LCD panels, as follows:

1.44-inch ILI9163-based displays

ILI9163-based displays use an SPI interface and have the following basic specifications:

- 1.44-inch LCD
- 128 × 128 pixels resolution
- 25.5 × 26.5mm viewing area
- Do not come with a touch controller
- Do not have an SD card socket

A typical ILI9163-based display is shown at right. You can find suitable displays on eBay by searching for the controller name, ie, ‘ILI9163’. Be warned that some displays with a red PCB won’t work with the Micromite Plus. Choose a display with a black PCB (as illustrated), as these have been tested and work correctly.

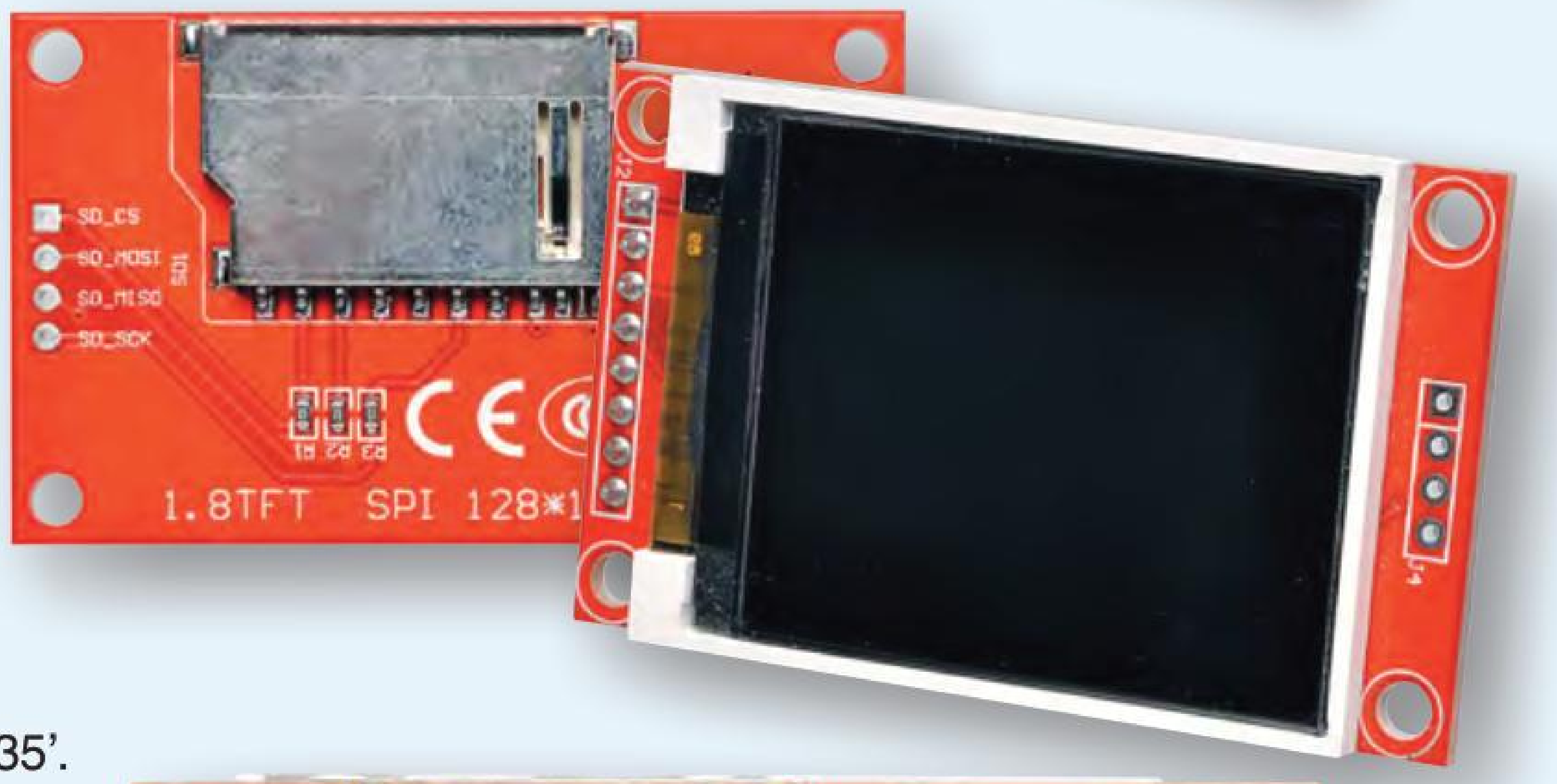


1.8-inch ST7735-based displays

The ST7735-based displays also use an SPI interface and have the following basic specifications:

- 1.8-inch LCD
- 160 × 128 pixel resolution and a colour depth of 262K/65K
- 38 × 35mm viewing area
- Do not come with a touch controller
- Have a full-size SD card socket

You can find suitable displays on eBay by searching for ‘ST7735’.



2.2 to 2.8-inch ILI9341-based displays

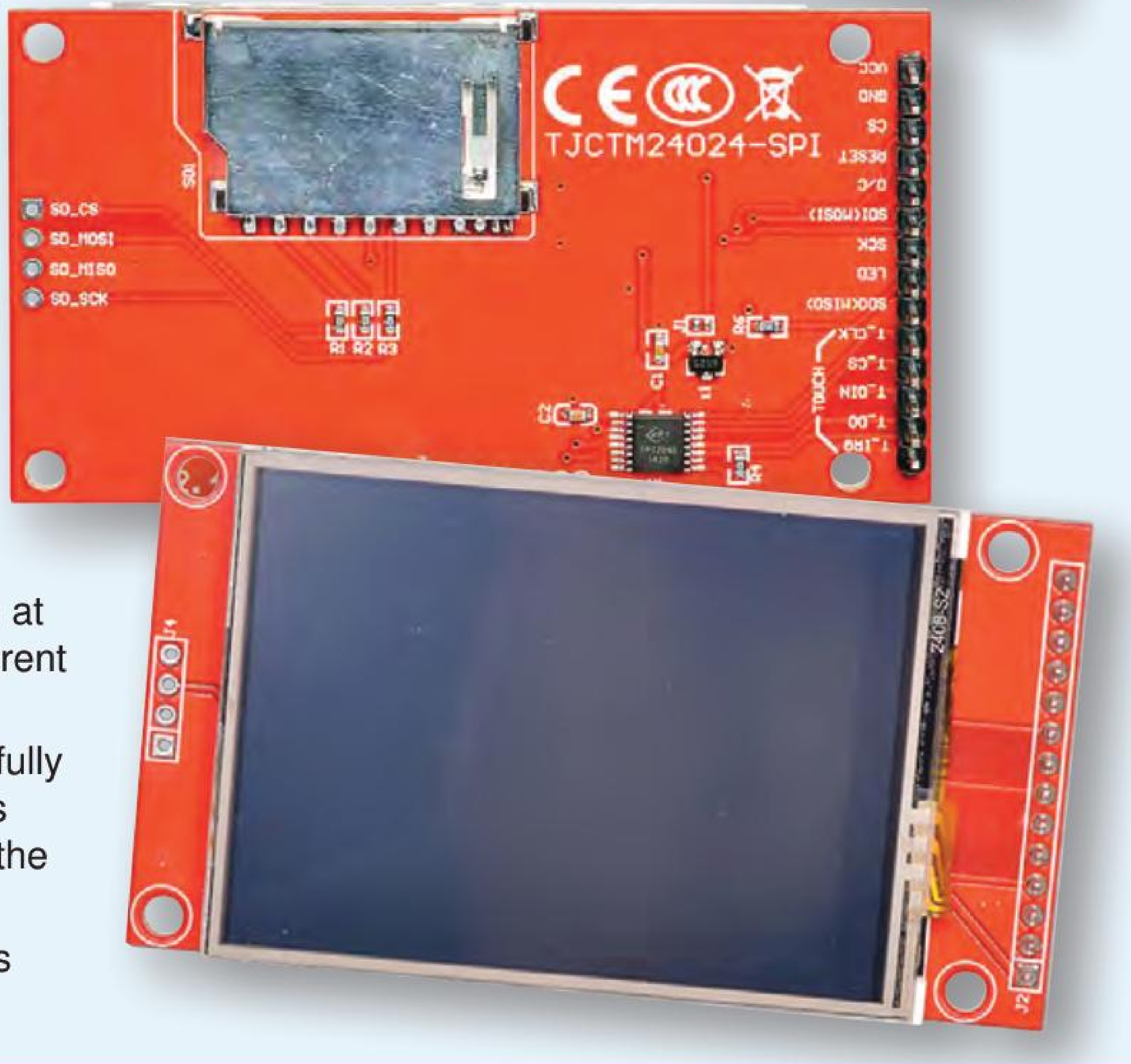
ILI9341-based displays use an SPI interface and have the following basic specifications:

- 2.2, 2.4, 2.6 or 2.8-inch LCD
- 320 × 240 pixel resolution and a colour depth of 262K/65K
- 43.5 × 35mm to 57.5 × 43mm viewing area
- May have a touch controller (SPI interface)
- Have a full-size SD card socket

The display that you purchase should look like the display shown at right, as there are other ILI9341-based displays which use a different interface and will not work with the Micromite.

In most cases, this display has a touch-sensitive facility which is fully supported by MMBasic. However, there are some versions of this display without the touch controller (the 16-pin IC on the back of the PCB at bottom right).

The standard Micromite also supports the ILI9341-based displays (both 28-pin and 44-pin versions).



The full selection of supported displays is listed in the above panel. Note that you do not have to use a display with the *Explore 64*; it is entirely optional and MMBasic will work perfectly well without one.

Having said that, using an LCD touchscreen is so simple and it adds such a professional air to a project that it is hard to think why you would not want to use one.

To configure the Micromite Plus for a particular LCD panel, use the **OPTION LCDPANEL** command. This comes in two forms. Displays with an SPI interface use this form:

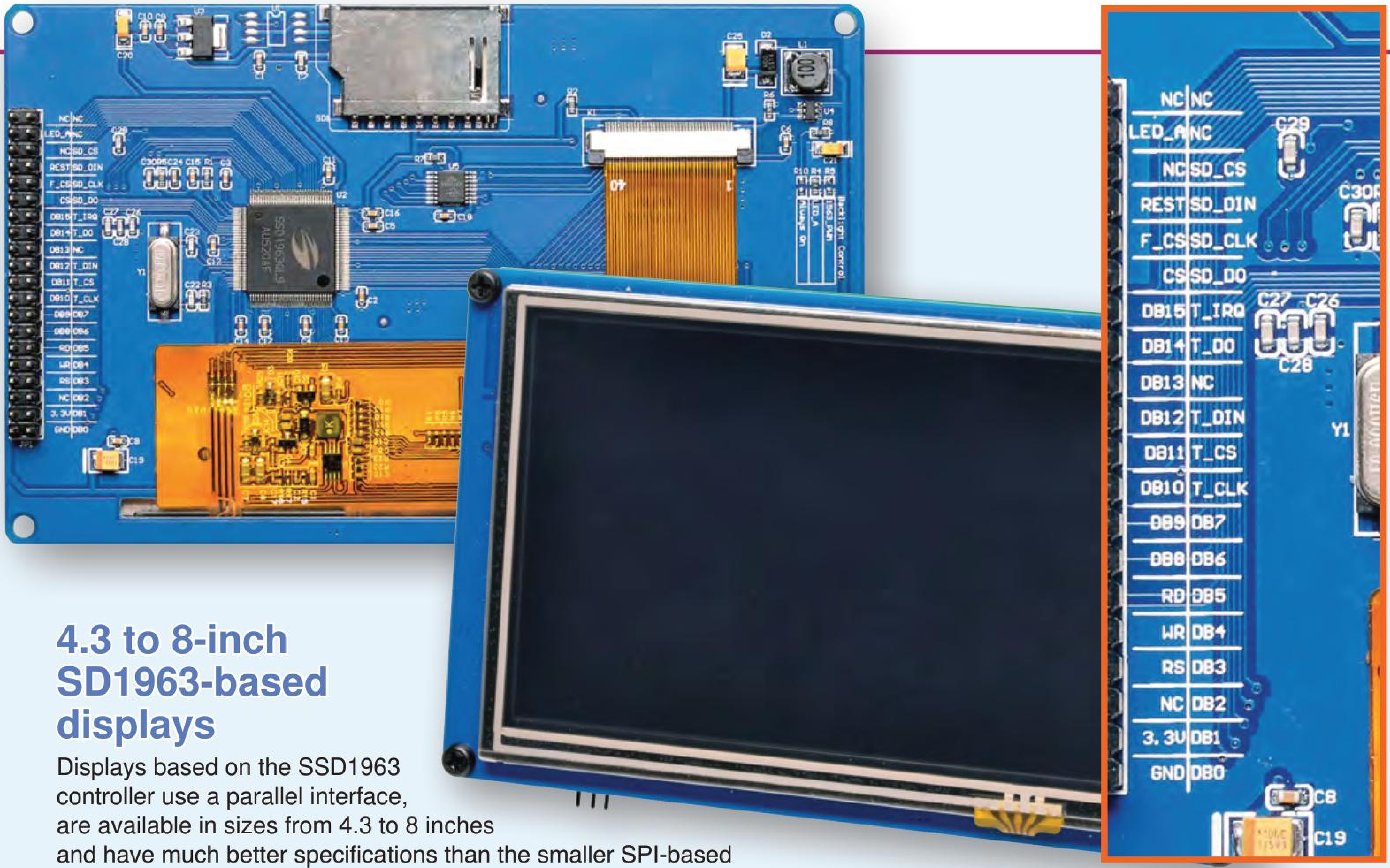
OPTION LCDPANEL controller, orientation, D/C pin, reset pin [, CS pin]

While displays that have a parallel interface use this form:

OPTION LCDPANEL controller, orientation [, LCD-A pin]

The ‘controller’ parameter defines what type of display controller chip is used on the display. This can be one of:

- **ILI9163:** a 1.44-inch display with an ILI9163 controller.
- **ST7735:** a 1.8-inch display with an ST7735 controller.
- **ILI9341:** A 2.2, 2.4, 2.6 or 2.8-inch 240 × 320 pixel display with an ILI9341 controller.
- **SSD1963_4:** a 4.3-inch display with an SSD1963 controller.



4.3 to 8-inch SD1963-based displays

Displays based on the SSD1963 controller use a parallel interface, are available in sizes from 4.3 to 8 inches and have much better specifications than the smaller SPI-based displays. The characteristics of supported SSD1963-based displays are:

- 4.3, 5, 7 or 8-inch LCD
- 480 × 272 pixels resolution for the 4.3-inch version; 800 x 480 pixel resolution for 5, 7 and 8-inch versions
- 95 × 54mm to 176.5 x 99mm viewing area
- SSD1963 display controller with a parallel interface (8080 format)
- Have a touch controller (SPI interface)
- Have a full-sized SD card socket

There are a number of different designs using the SSD1963 controller but fortunately **most Chinese suppliers have standardised on a single connector as illustrated in the photo at top right.** It is strongly recommended that any display purchased has this type of connector so that you can be reasonably confident that the manufacturer has followed the standard that the Micromite Plus is designed to use.

The 8-inch display supplied by the Chinese company EastRising uses a different connector layout to that shown, However, it has been tested with the Micromite Plus and works perfectly.

- **SSD1963_5:** a 5-inch display with an SSD1963 controller.
- **SSD1963_5A:** an alternative version of the 5-inch display if SSD1963_5 doesn't work.
- **SSD1963_7:** a 7-inch display with an SSD1963 controller.
- **SSD1963_7A:** an alternative version of the 7-inch display if SSD1963_7 doesn't work.
- **SSD1963_8:** an 8-inch display supplied by the Chinese company EastRising (**www.buydisplay.com**).

The 'orientation' parameter specifies the normal position of the display which might be mounted in a portrait orientation or even upside-down. Your choices for this parameter are **LANDSCAPE**, **PORTRAIT**, **RLANDSCAPE** or **RPORTRAIT**. These can be abbreviated to **L**, **P**, **RL** or **RP**. The **R** prefix indicates the reverse or 'upside down' orientation.

The remaining parameters in the command specify some of the I/O pins used for the display. There are other pins that are dedicated when you specify a type of display as listed in the 'Micromite Plus Addendum'. This specifies exactly how to connect a display and what I/O pins to use.

To test the display, use the command:

GUI TEST LCDPANEL

You should immediately see an animated display of colour circles being rapidly drawn on top of each other (Fig.6). Pressing the space bar on the console's keyboard stops the test.

Configuring touch

Most displays are supplied with a resistive touch-sensitive panel and its associated controller chip. To use the touch feature in MMBasic, the touch controller must first be connected to the Micromite Plus and then configured. The connections for the touch controller are different on each LCD panel, so refer to the *Micromite Plus Addendum* for the details.

MMBasic is configured for touch using the **OPTION TOUCH** command at the command prompt (not in a program). This should be done after the LCD panel has been configured. The syntax is:

OPTION TOUCH T_CS pin, T_IRQ pin [, click_pin]

Here, **T_CS pin** and **T_IRQ pin** are the Micromite I/O pins to be used for chip select and touch interrupt respectively (any free pins can be used).

The 'click_pin' parameter is optional and specifies an I/O pin that will be driven briefly high when a screen control is touched. This can be used to drive a small piezo buzzer which will produce a click sound, thereby providing an audible feedback whenever a GUI element on the screen is activated. We will cover this subject in detail in a

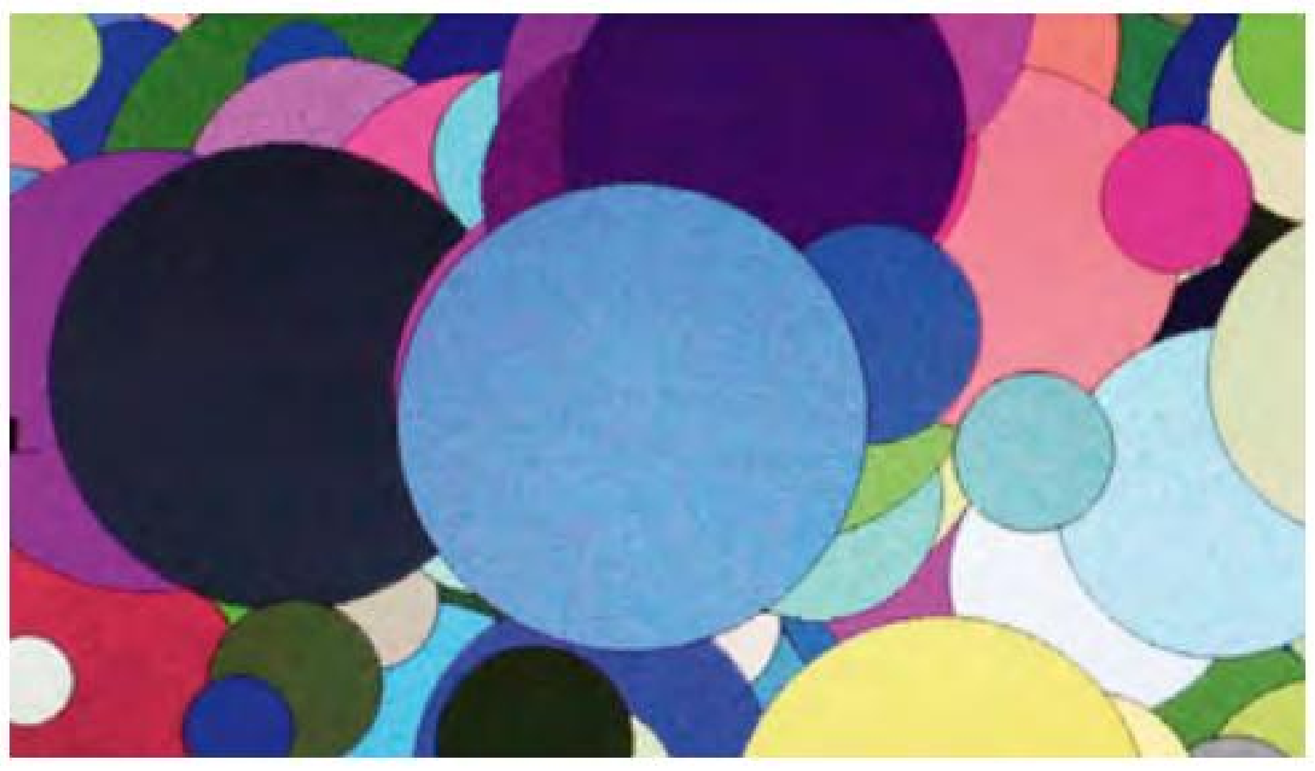


Fig.6: this is the display that you will see on the LCD when the command GUI TEST LCDPANEL is used. The display is animated with the circles being rapidly drawn on top of each other.

When using an LCD panel that has an SSD1963 controller, the Micromite Plus can display 800x480 pixels in true (24 bit) colour. This image of a tiger demonstrates the resolution and colour range.

future article, where we describe the on-screen graphic (GUI) controls.

As with other options, this command only needs to be run once. Thereafter, every time the Micromite is restarted, MMBasic will automatically initialise the touch controller. If the touch facility is no longer required, the command **OPTION TOUCH DISABLE** can be used to disable the touch feature and return the I/O pins for general use.

Before the touch facility can be used, it must be calibrated using the **GUI CALIBRATE** command. The calibration processes starts with MMBasic displaying a target in the top-left corner of the screen. A blunt pointed object such as a stylus is then pressed exactly on the centre of the target and held down for at least one second. MMBasic will record this location and then continue the calibration by sequentially displaying the target in the other three corners of the screen.

Following calibration, you can test the touch facility using the **GUI TEST TOUCH** command, which will blank the screen and wait for a touch. When the screen is touched with a stylus, a white dot will appear on the display. If the calibration was carried out successfully, this dot will be displayed exactly under the location of the stylus.

Pressing the space bar on the console's keyboard exits the test routine.

Touch functions

It's easy to use the touch interface with MMBasic. There are eight functions that provide useful information, as follows:

TOUCH(X) – returns the X coordinate of the currently touched location.

TOUCH(Y) – returns the Y coordinate of the currently touched location.

TOUCH(DOWN) – returns true if the screen is currently being touched (this is much faster than **TOUCH(X)** or **TOUCH(Y)**).

TOUCH(UP) – returns true if the screen is currently NOT being touched (also faster than **TOUCH(X)** or **TOUCH(Y)**).

TOUCH(LASTX) – returns X coordinate of the last location that was touched.

TOUCH(LASTY) – returns Y coordinate of the last location that was touched.

TOUCH(REF) – returns the reference number of the control that is currently being touched or zero if no control is being touched. We will cover this subject in depth in a future article.

TOUCH(LASTREF) – returns the reference number of the control that was last touched.

You can also set up an interrupt subroutine to be called when the screen is touched or touch is removed. A touch interrupt is important when you are using the GUI controls.

These powerful functions make employing the Micromite Plus as a controller a dream and we will cover them in more detail in a future article.

That's all for now. In coming months, we will present the *Explore 100*, which can be mounted on the back of a 5-inch display to make a complete controller or self-contained computer.

Firmware updates

For firmware updates and other information relating to the Micromite Plus, check the author's website at: **geoffg.net/micromite.html**

Acknowledgements

My thanks to Graeme Rixon who designed the Explore 64 PCB and helped with its development.

My thanks also to the many members of the Back Shed forum who acted as beta testers during the Micromite Plus' long development. The forum also has many members who are happy to help newcomers to the Micromite series. You can find it at: **thebackshed.com/forum/Microcontrollers**

Win an Explore 64!

EPE is running a competition to win a fully-assembled Explore 64 thanks to the generous sponsorship of Micromite online shop **micromite.org**

For entry details, please turn to page 39.

Explore 64 parts

IMPORTANT!

Micromite truly straddles the globe! First and foremost, the on-going series of microcontrollers is designed and developed by Geoff Graham in Australia. Do visit his website for firmware updates and the latest Micromite news: **geoffg.net/micromite.html**

Many of the PCB designs come from Graeme Rixon in New Zealand, and now there is a UK online shop for all things Micromite-related, run by Phil Boyce at: **micromite.org**

We strongly recommend you make **micromite.org** your first port of call when shopping for all Micromite project components. Phil can supply kits, programmed ICs, PCBs and many of the sensors and other devices mentioned in recent articles – in fact, just about anything you could want for your Micromite endeavours.

Phil is not just another online vendor of assorted silicon. He works closely with Geoff Graham and is very knowledgeable about the whole series of Micromite microcontrollers.

WIN A Micromite!

MICROMITE

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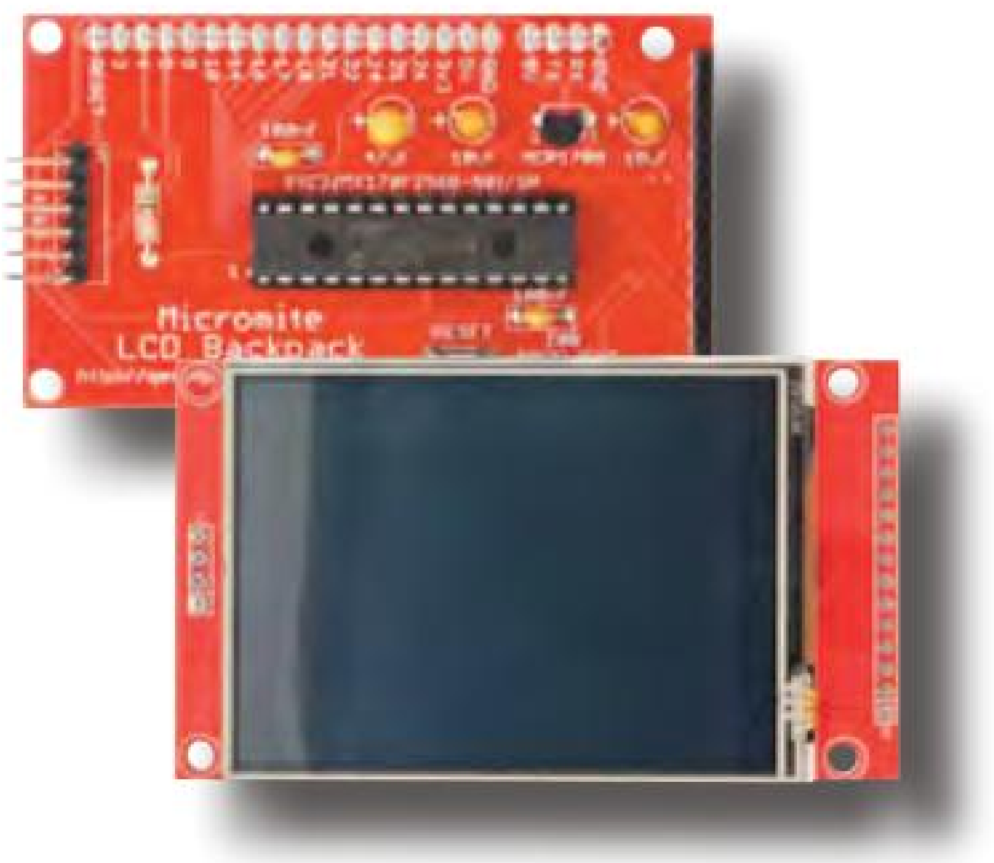


Two fantastic Micromite prizes are up for grabs this month thanks to the team at: **micromite.org**

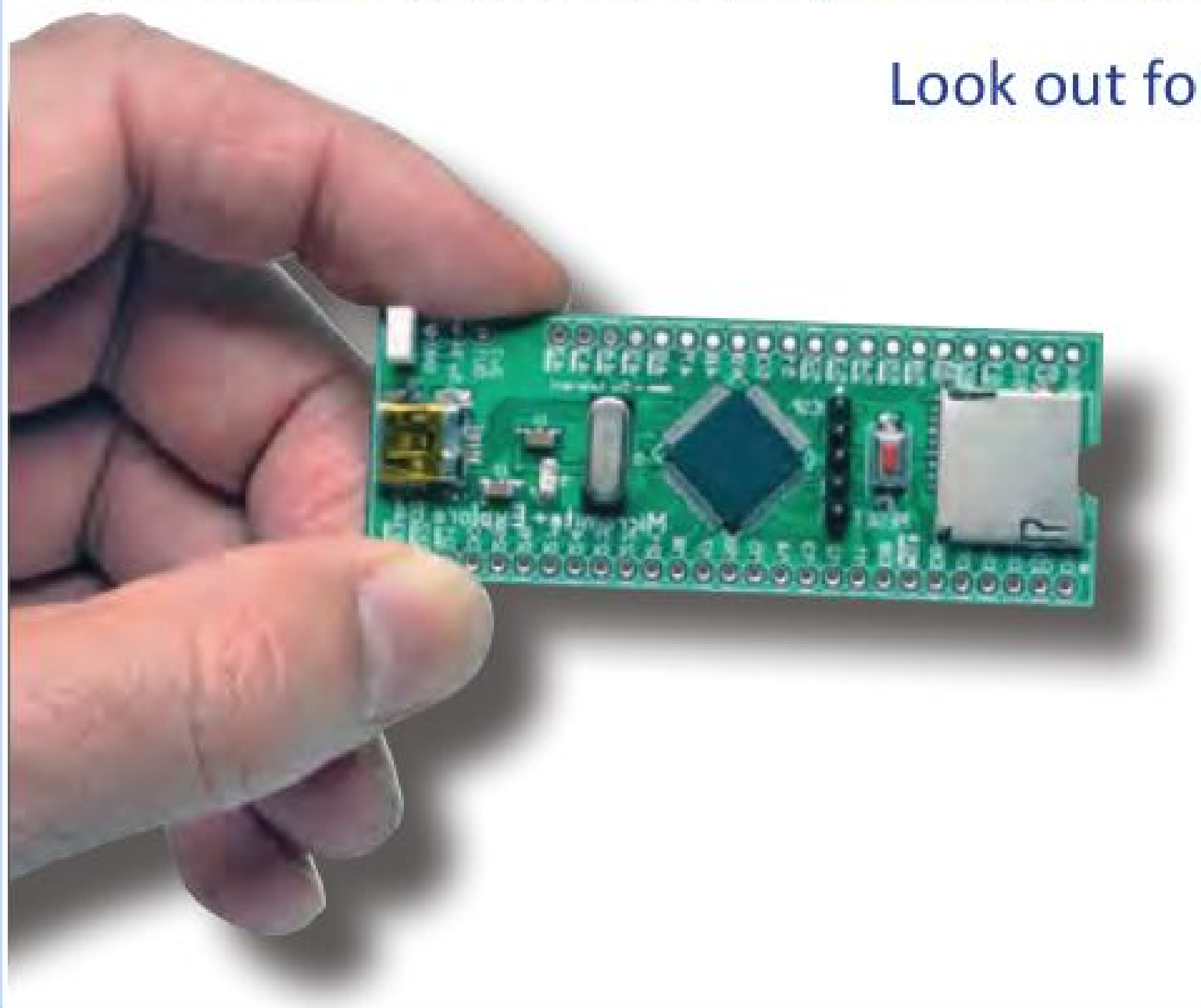
1. A Fully Assembled Explore64 Module (E64) (RRP £29.95)
2. A Micromite LCD Backpack Kit complete with 2.8" TouchScreen (BP28) (RRP £38.95)

To have a chance to win, the guys at Micromite want you to put on your thinking caps and answer the following question:

"I would use my Micromite to . . . . ."

Your answer can be as short, or as long, as you like. We are looking for 'creativity' here, so let your imagination run wild. Simply send your answer via email to: **epe@micromite.org** before **31st July**

Make the email subject either **E64** or **BP28** depending on which competition you wish to enter (you may even enter both!). The names of the two lucky winners will be published in a future edition of *EPE*.



Look out for future competitions to win other fantastic Micromite products

(Next month: Win an Explore100)

Good Luck!

T&Cs

1. You may enter as many times as you wish
2. All entries must be received by the closing date
3. Winners will be notified by email within one week after the closing date
4. Winners will need to confirm a valid address for their prize to be shipped
5. UK winners will have their prize sent via Royal Mail's Special Delivery service
6. Overseas winners will have their prize sent by Royal Mail's International Tracked & Signed service

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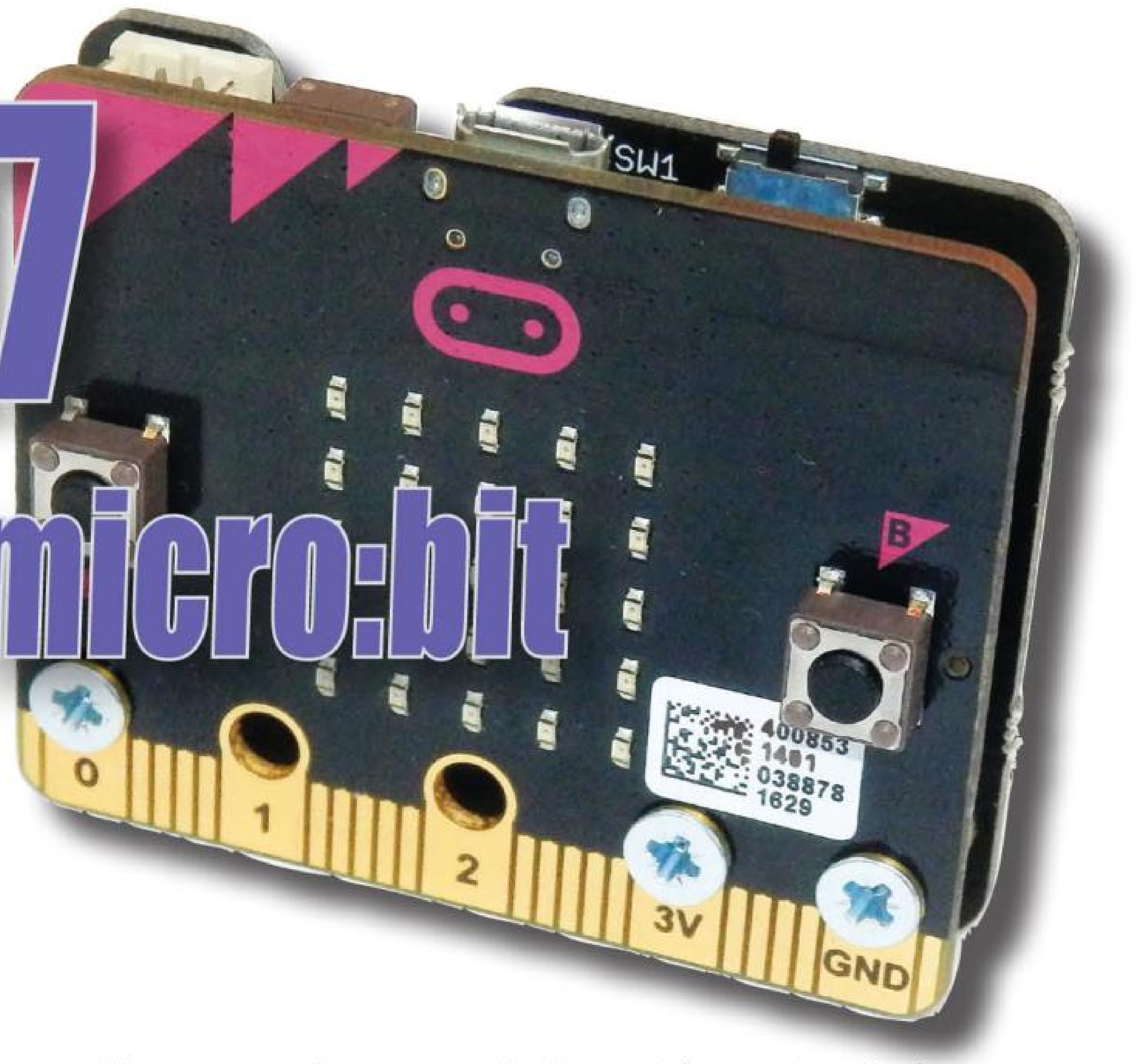
Teach-In 2017

Introducing the BBC micro:bit

Part 3: Analogue I/O



by Mike Tooley

Welcome to *Teach-In 2017 – Introducing the BBC micro:bit*. Following on from our popular *Teach-In series* on the Arduino (and previously the Raspberry Pi), Mike Tooley has extended his investigation of low-cost microcontrollers to the recently introduced BBC micro:bit. Not just an educational resource for teaching kids coding, this tiny low-cost microcontroller provides you with yet another solution to the problem of controlling a wide range of electronic projects, ranging from simple domestic gadgets to more complex control systems such as those used for lighting, central heating and security applications. To get you up and running quickly, each *Teach-In* concludes with a simple but useful practical project. In this third part, Mike will be delving into analogue I/O and our practical project shows how a micro:bit can be used with a low-cost analogue temperature sensor and a two-channel relay module to form the basis of a thermostatic controller.

Analogue I/O with the micro:bit

Last month, we looked at digital I/O and, as we explained, digital signals can only exist in one of two discrete states (high and low, or on and off). This month, we turn our attention to the analogue world; a world in which signals are continuously variable. In order to work with analogue signals the micro:bit has its own built-in analogue-to-digital converter (ADC).

The micro:bit's 10-bit ADC accepts analogue inputs over a nominal range of 0 to +3.3V, and converts them to corresponding 10-bit digital codes. This means that an analogue input of 0V will be represented by a binary value of 0000000000, while a value of approximately 3.3V will be represented by a binary value of 1111111111. This corresponds to a range extending from 0 to 1023 when expressed in decimal – see Table 3.1. Each increment in output from the ADC corresponds to a change of around 3.2mV. This is the smallest change in analogue level that the micro:bit can recognise and it is adequate for a use in a number of simple applications.

Table 3.1 Range of micro:bit analogue output values

Output data	Binary equivalent	Mean output (approx.)
0	0000000000	0V
1	0000000001	0.003V
2	0000000010	0.006V
3	0000000011	0.010V
4	0000000100	0.013V
5	0000000101	0.016V
etc…	etc…	etc…
511	0011111111	1.635V
512	0100000000	1.638V
513	0100000001	1.641V
etc…	etc…	etc…
1022	1111111110	3.297V
1023	1111111111	3.300V
>1024	1111111111	+3.3V

Reading analogue inputs

The micro:bit's edge connector provides you with three pins that can be used for analogue I/O without affecting other micro:bit functions. These are pins 0, 1 and 2. In order to read the analogue voltage present at one of these pins Micropython provides you with the `read_analog()` function. The value returned from the function can be assigned to a variable of your choice (for example, `value`, as shown in Listing 3.1). Note that we also need to specify the analogue pin that we are reading (in this case, pin-0).

To test the code shown in Listing 3.1 you can simply connect a variable potentiometer (of 10kΩ, or more) as shown in Fig.3.1 and Fig.3.2. You should find, with the code running, the micro:bit will display a reading in the range 0 to 1023 at the two extreme settings of the potentiometer.

The reference voltage for the micro:bit's 10-bit ADC is derived from the chip's nominal 3V supply. In practice, this voltage can vary from

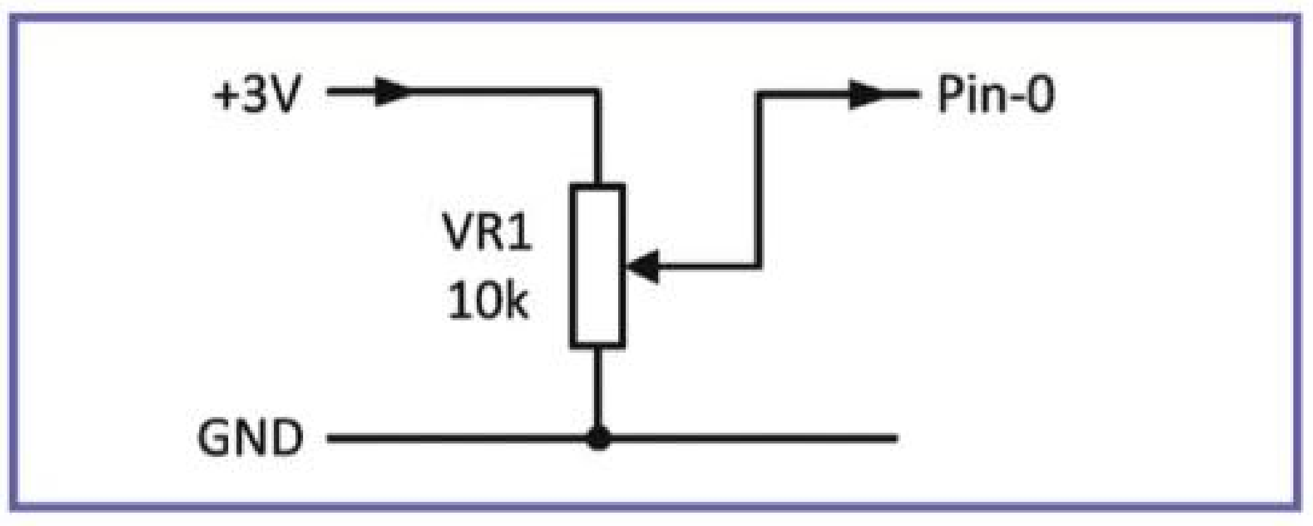


Fig.3.1. Testing the micro:bit's analogue I/O

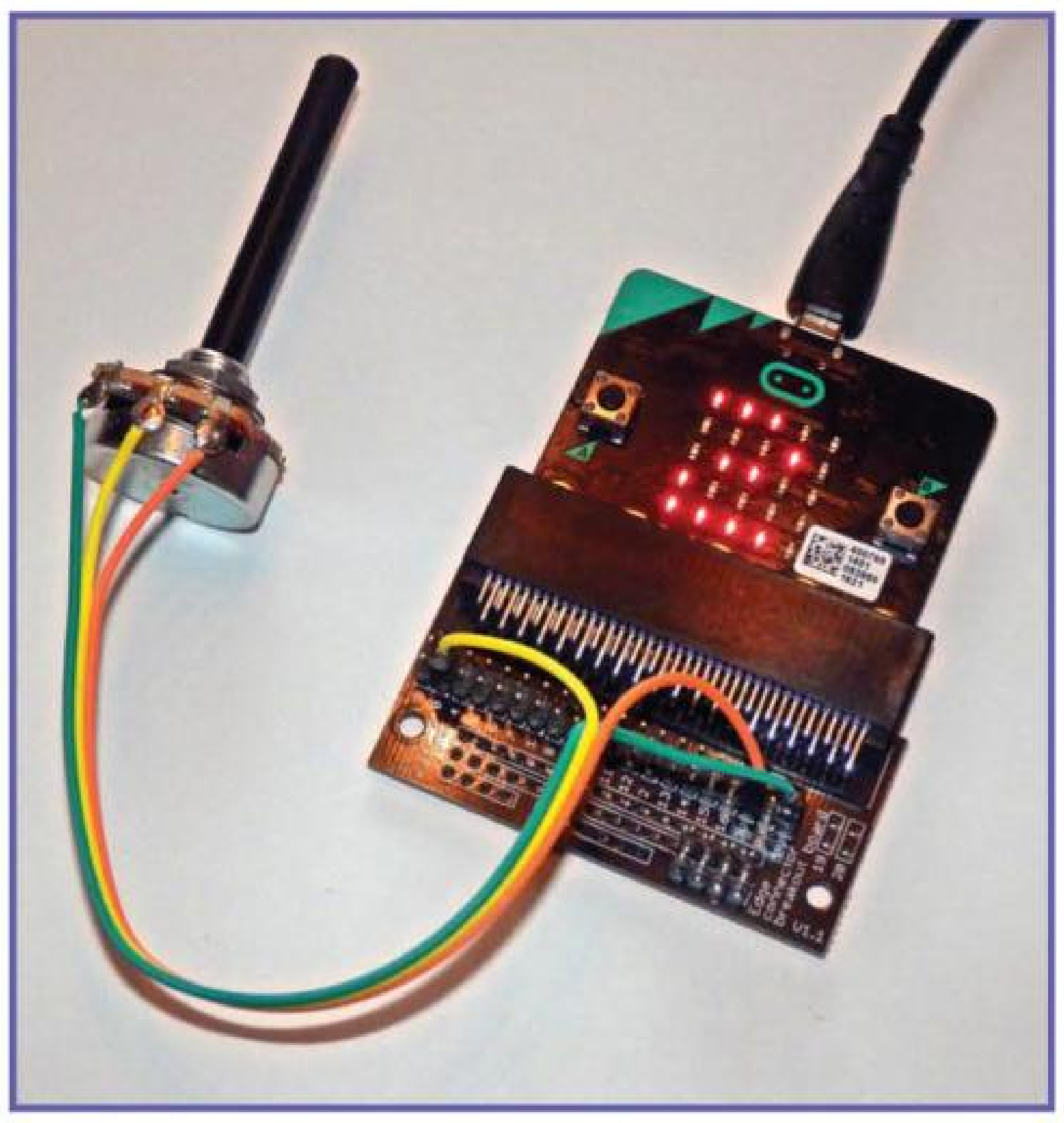


Fig.3.2. Connect the potentiometer to the micro:bit. The slider (yellow wire) is taken to the analogue input pin

Listing 3.1 Reading an analogue input

```
from microbit import *

while True:
    value = pin0.read_analog()
    display.show(str(value))
    display.show(" ")
    sleep(1000)
```

Listing 3.2 Writing an analogue output

```
from microbit import *

while True:
    value = 511
    display.show(str(value))
    pin0.write_analog(value)
    display.show(" ")
    sleep(1000)
```

around 3V to as much as 3.3V depending on the power source and the total load present. This, in turn, imposes a limit on the accuracy of analogue readings, but later in our practical project we will show how you can compensate for this error.

Writing analogue outputs

In order to output an analogue voltage from one of the micro:bit's available I/O pins, Micopython provides you with the `write_analog()` function. The code shown in Listing 3.2 can be used to output an analogue voltage in the range 0V to +3.3V. The *mean* voltage at the output is determined by the value written to the analogue I/O pin and, in this case the value indicated on the DC voltmeter should be approximately 1.6V (see Table 3.1). If you now change the value to 1023 and re-flash the code, the value indicated should increase to around 3.2V (the maximum possible).

Notice that we just used the phrase 'mean voltage'. This is rather important because the micro:bit is not actually capable of producing a true analogue output. Instead it produces a pulse-width modulated (PWM) digital waveform. The waveform has a constant amplitude (approximately 3.3V) and a duty cycle that depends on the data value that's being written to the ADC. A duty cycle of 100% (ie, a continuous high-state output) will result from a data value of 1023, while a duty cycle of 0% (a continuous low output) will result from a data value of 0. A 50% duty cycle (where the high and low times are almost identical) will correspond to a data value of 511.

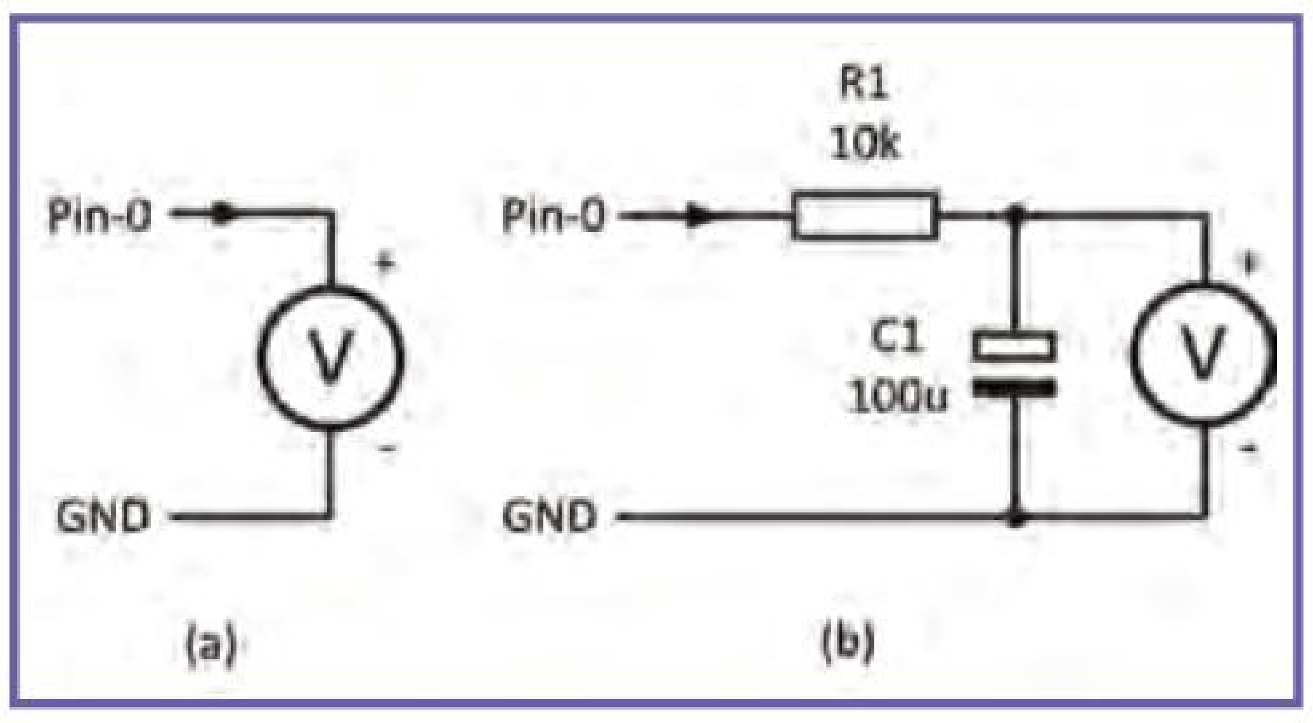


Fig.3.3. Using a voltmeter to read the mean output voltage

Listing 3.3 Reading and writing analogue data

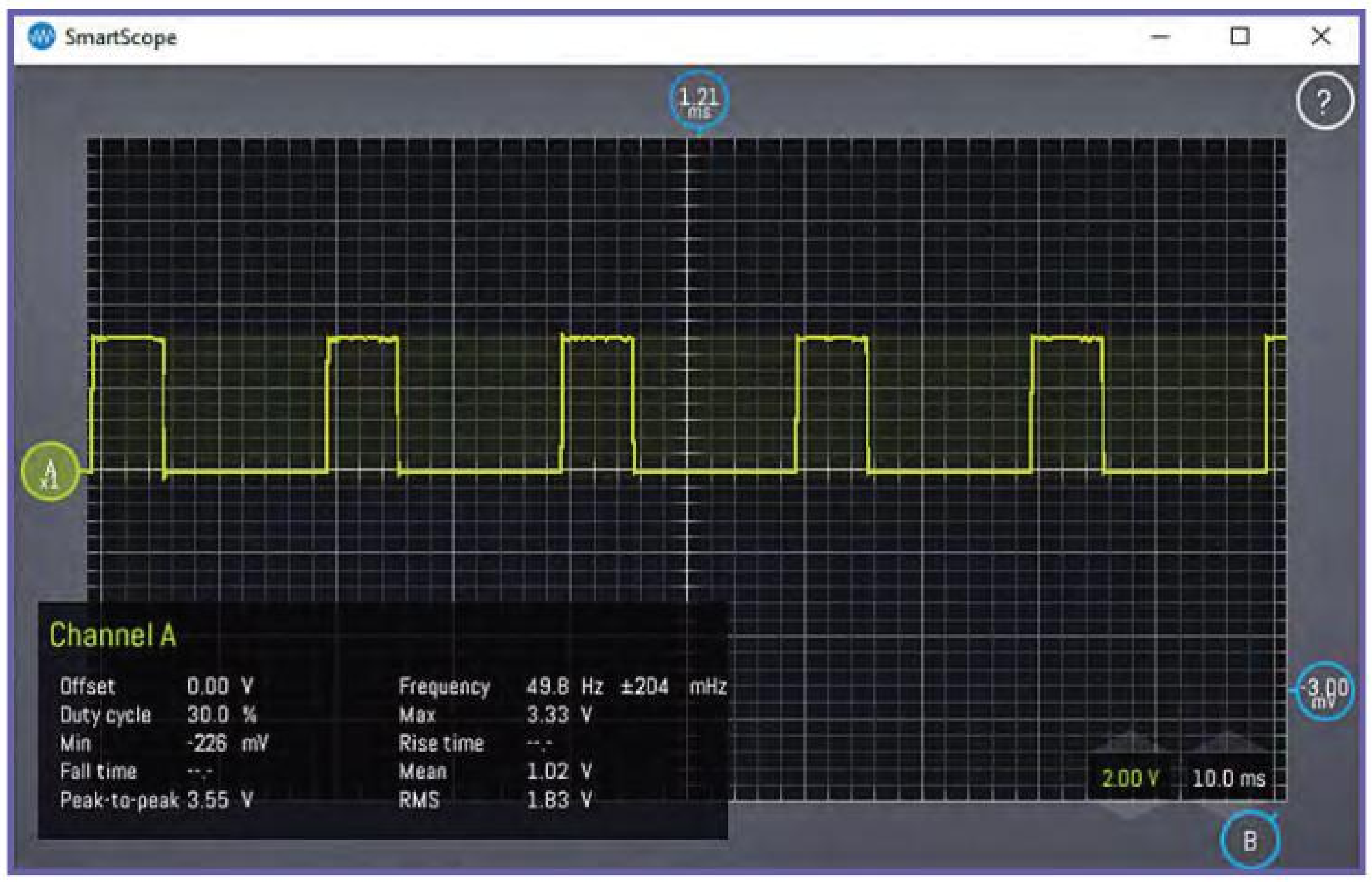
```
from microbit import *

while True:
    value = pin1.read_analog()
    display.show(str(value))
    pin0.write_analog(value)
    display.show(" ")
    sleep(1000)
```

We can read the mean output voltage reasonably reliably using a conventional voltmeter, as shown in Fig.3.3(a) but to produce a more constant output voltage we can make use of a simple CR low-pass averaging filter, like that shown in Fig.3.3(b).

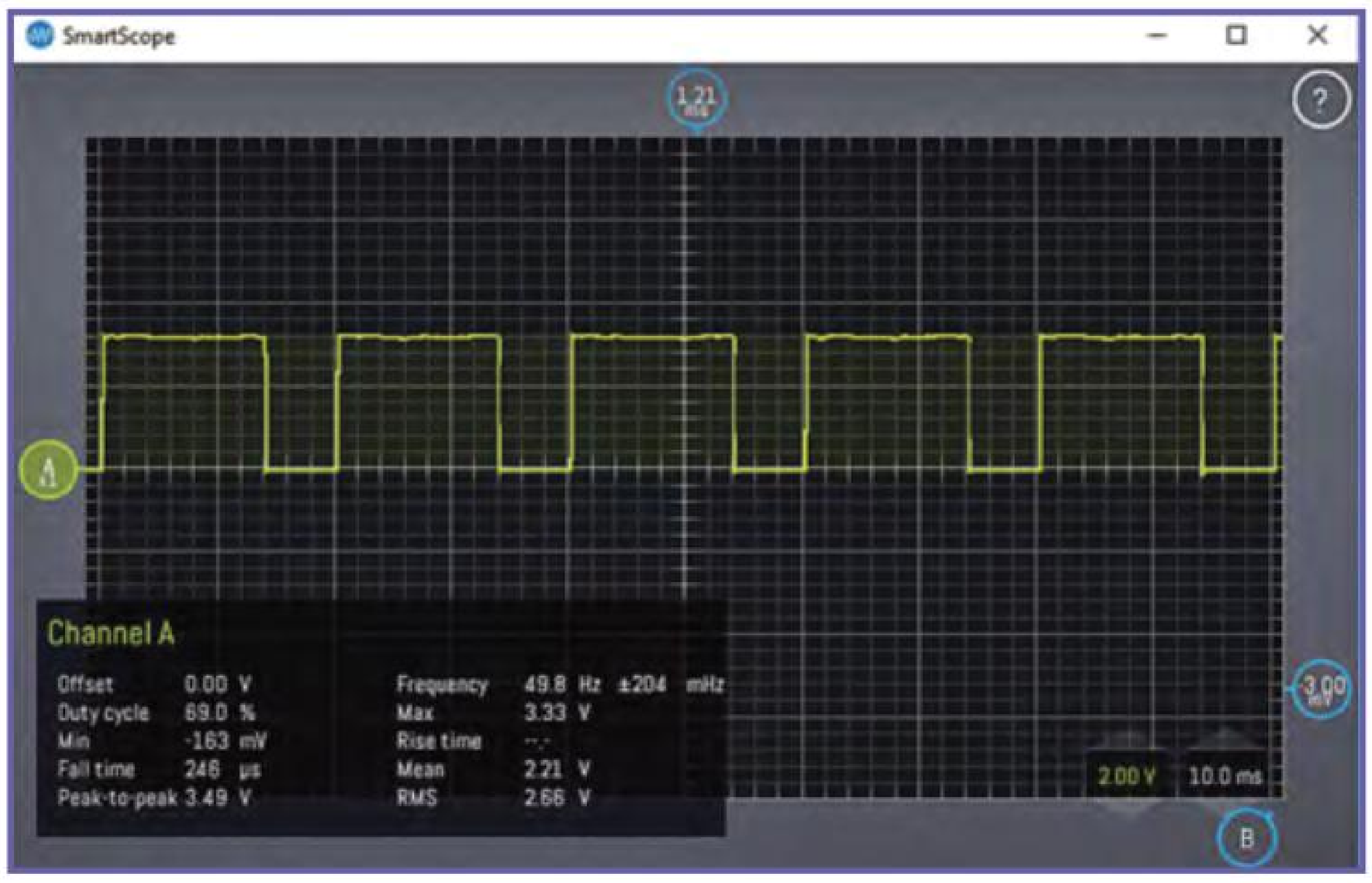
PWM output waveforms

Fig.3.4 shows the output waveform at pin-0 for a 30% duty cycle (corresponding to a mean output of just over 1V) while Fig.3.5 shows the output waveform at pin-0 with a 70% duty cycle (corresponding to an output of approximately 2.2V). As mentioned earlier, in order to produce a more constant voltage level (rather than a series of pulses) we can smooth the output using a simple RC low-pass filter, like that shown in Fig.3.3(b). Fig, 3.6 shows how this affects the output waveform. Note that in all cases the output is at a high-impedance level and, although the voltage will appear reasonably accurate when measured using a voltmeter or an oscilloscope, it will *not* be correct when a low-resistance load is present at the output.



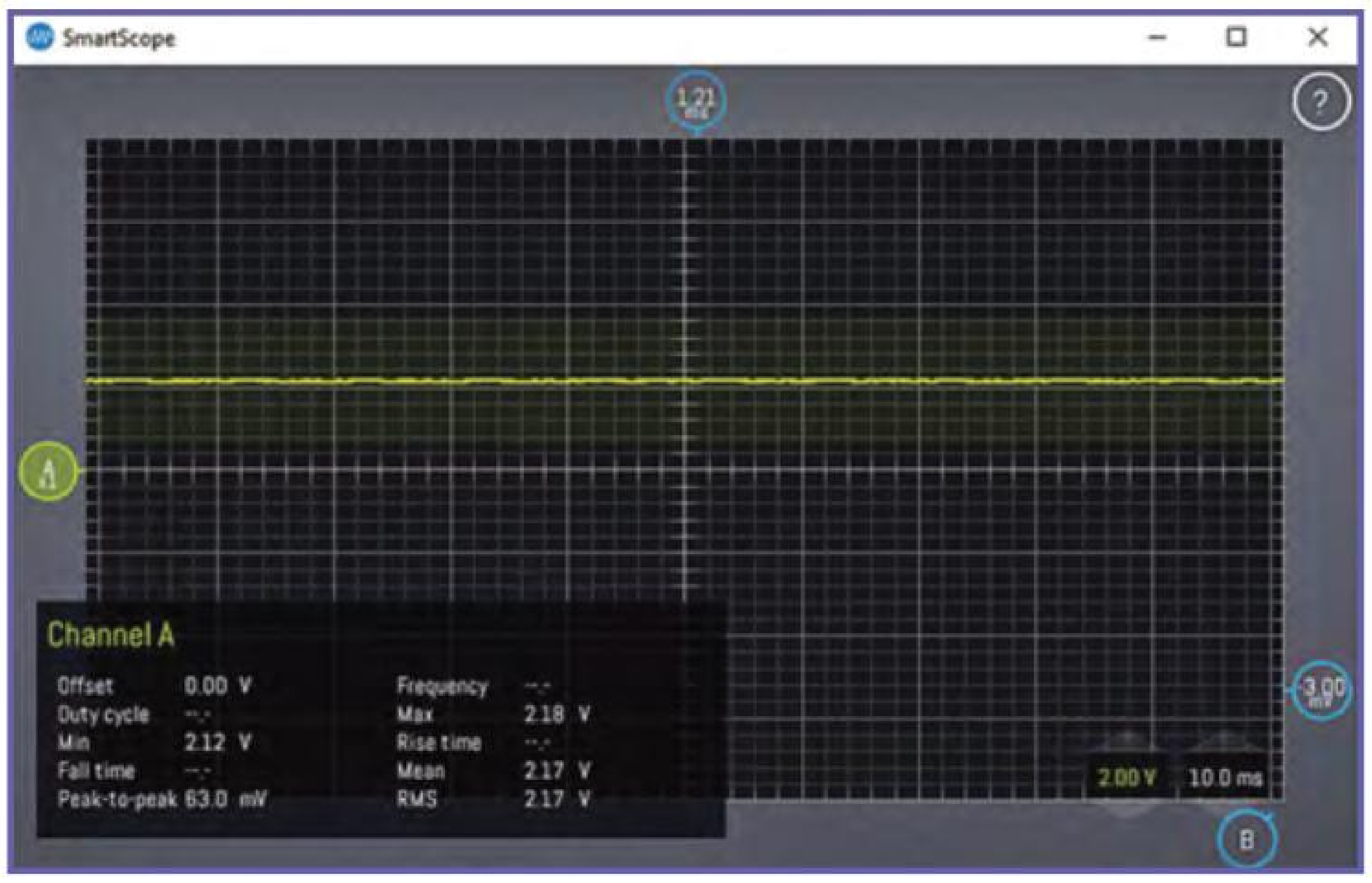
```
Channel A
Offset         0.00  V       Frequency   49.8  Hz  ±204  mHz
Duty cycle     30.0  %       Max         3.33  V
Min            -226  mV      Rise time   --.-
Fall time      --.-          Mean        1.02  V
Peak-to-peak   3.55  V       RMS         1.83  V
```

Fig.3.4. PWM output with 30% duty cycle



```
Channel A
Offset         0.00  V       Frequency   49.8  Hz  ±204  mHz
Duty cycle     69.0  %       Max         3.33  V
Min            -163  mV      Rise time   --.-
Fall time      246   µs      Mean        2.21  V
Peak-to-peak   3.49  V       RMS         2.66  V
```

Fig.3.5. PWM output with 70% duty cycle



```
Channel A
Offset         0.00  V       Frequency   --.-
Duty cycle     --.-          Max         2.18  V
Min            2.12  V       Rise time   --.-
Fall time      --.-          Mean        2.17  V
Peak-to-peak   63.0  mV      RMS         2.17  V
```

Fig.3.6. Effect of the RC low-pass filter in Fig.3.3(b)

Reading and writing analogue data in the same application

You may sometimes find that you need to read and write analogue data in the same application. For example, when using a variable potentiometer to control the speed of a small DC motor. This can be easily done using code based on the example shown in Listing 3.3. In this case, we are using pin-0 for analogue (PWM) output and pin-1 for analogue input.

The code example shown in Listing 3.3 can be quite instructive. Using the arrangement shown in Fig.3.7 (and with a voltmeter connected to the output) you will find that the output voltage level can be easily adjusted to any desired voltage over the range 0V to +3.2V.

Determining the input and output voltage

The micro:bit ADC input voltage can be calculated from the relationship:

$$V_{in} = value \times \left(\frac{V_{ref}}{1023} \right)$$

Where **value** is the variable returned from the **read_analog()** statement.

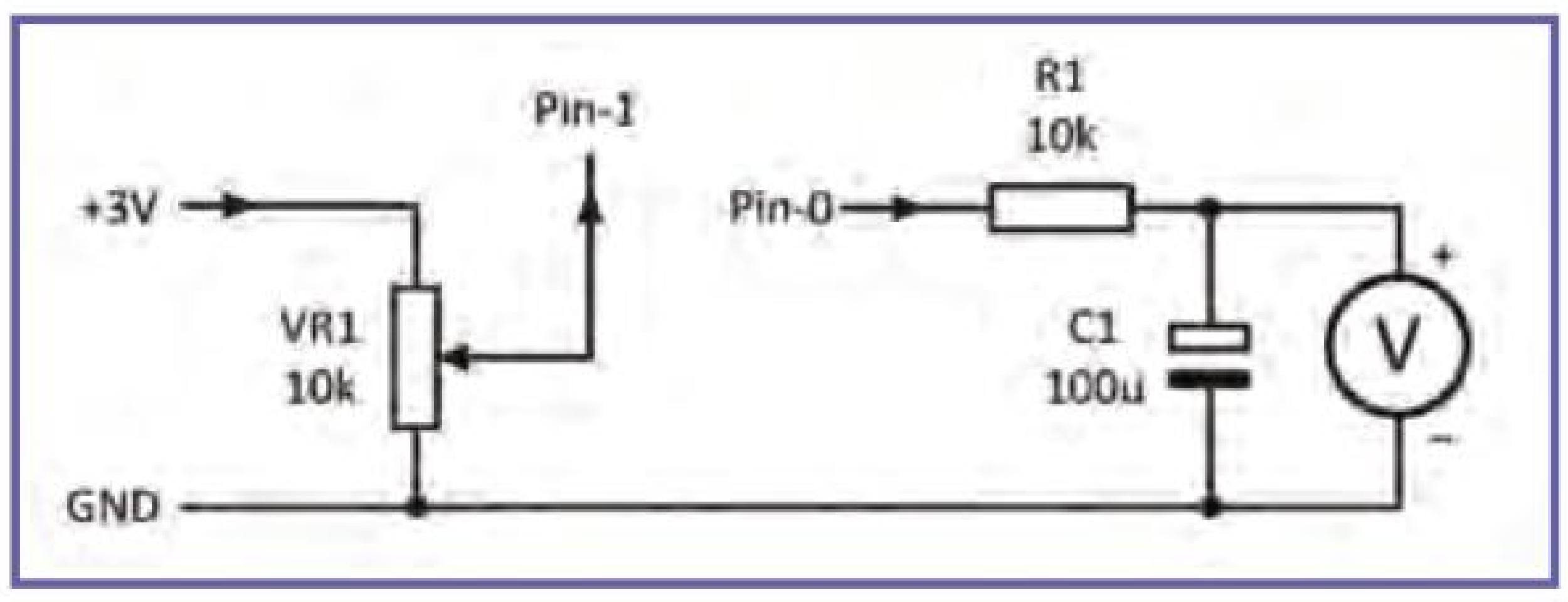


Fig.3.7. Arrangement for testing Listing 3.3

Note that **`value`** can take a value between 0 and 1023.

Conversely, the value to write to the micro:bit's ADC in order to generate a PWM waveform with a specified mean (see earlier) can be calculated from the relationship:

$$value = V_{out} \times \left(\frac{1023}{V_{ref}}\right)$$

Where **`value`** is to be placed in the variable that will be sent to the the `write_analog()` function. Once again, **`value`** should be in the range 0 to 1023.

Note that, in both of these relationships, V_{ref}, is the ADC reference voltage which, as mentioned earlier, is derived directly from the micro:bit's supply and might, in practice be anything between 3V and 3.3V. To put this into context, here are two examples that assume that we are using a nominal 3.3V DC reference.

Example 3.1

If a value of 795 is returned by the **`read_analog()`** function, then the corresponding input voltage will be:

$$V_{in} = 795 \times \frac{3.3}{1023} = 2.56\text{V}$$

Example 3.2

If a mean output of 0.5V is required, the data value to use with **`write_analog()`** will be given by:

$$V_{out} = 0.5 \times \frac{1023}{3.3} = 155$$

Setting the period of the PWM output

If necessary, the **`set_analog_period()`** function can be used to configure the period of the PWM waveform on the specified analogue pin (eg, pin-0, pin-1 or pin-2). For example, **`pin0.set_analog_period(20)`** sets the analogue period of the PWM waveform generated on pin-0 to 20ms, while **`pin1.set_analog_period_microseconds(400)`** sets the analogue period of the PWM output on pin-1 to 400µs.

Project: A micro:bit Thermostatic Controller

Our practical projects have been designed to provide you with hands-on experience of using the BBC micro:bit.

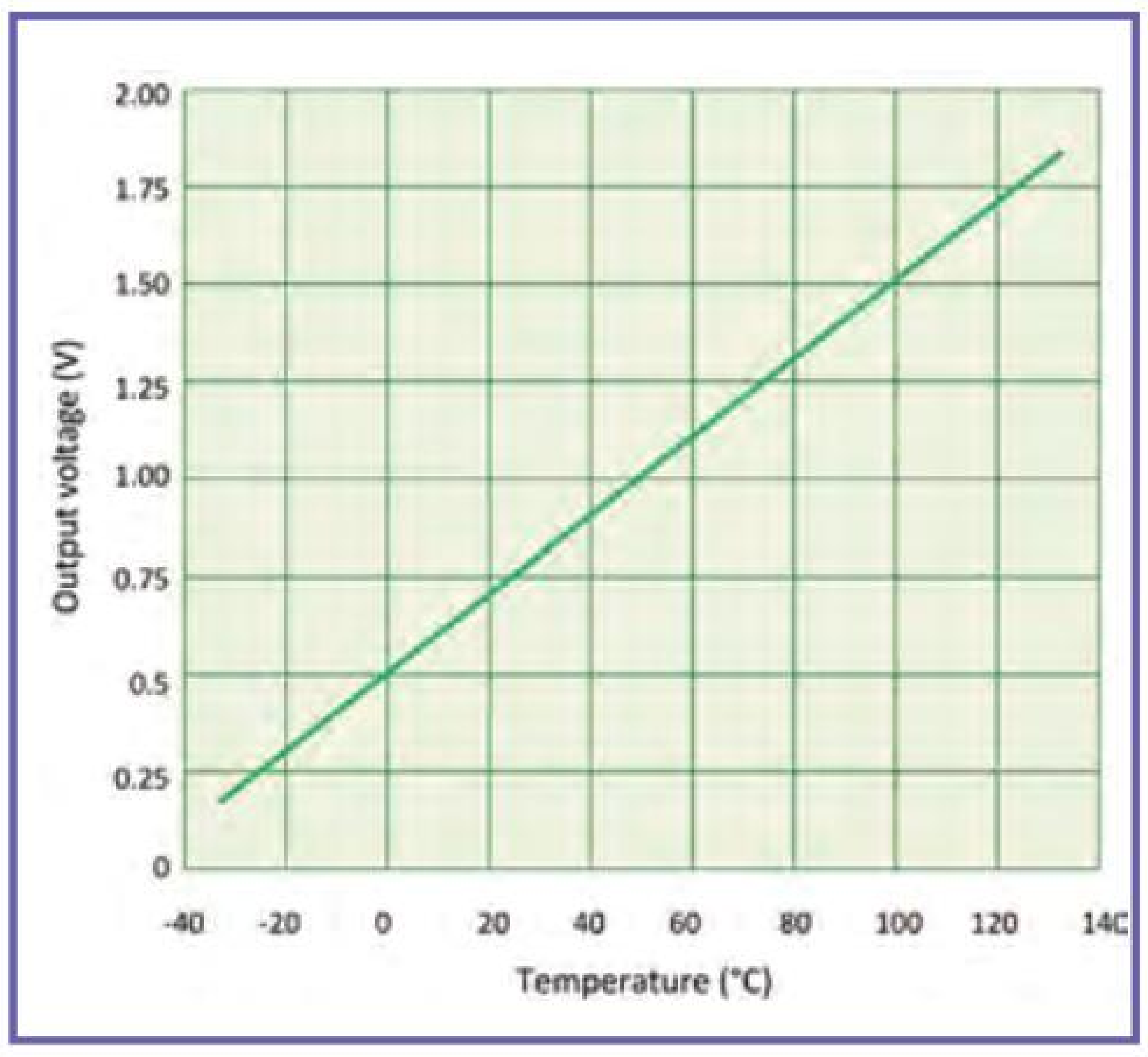


Fig.3.9. The TMP36 temperature sensor characteristic

In last month's practical project we used the Microsoft Block editor to produce a simple electronic spirit level. This month, we will be describing another simple micro;bit gadget that takes the form of a thermostatic controller. It would be ideal for maintaining the temperature in a small greenhouse or conservatory.

Our *micro:bit Thermostatic Controller* uses a TMP36 low-cost analogue temperature sensor (IC1) and a two-channel solid-state relay module, see Fig.3.8. The 5V supply for the *micro:bit Thermostatic Controller* is derived from a dual output rechargeable USB battery pack. These are available at low-cost from numerous suppliers and one rated at 4500mAh should be adequate for many hours of continuous operation.

The TMP36 sensor provides an analogue output voltage that varies linearly over a temperature range extending from –20°C to +120°C, as shown in Fig.3.9. Thus, an output voltage of 0.5V from IC1 (see Fig.3.8) will appear when the ambient temperature is 0°C, while an output of 1.5V will appear at 100°C. Thus, for every 1°C change in temperature the output voltage from the sensor will change by 10mV. This makes the TMP36 very easy to use and all we need to do is to use a little mathematics to convert DC input voltages into their corresponding data values in Celsius. The micro:bit is ideal for this task!

The TMP36 sensor can be mounted on a small piece of strip-board (see Fig.3.10) and easily linked to the micro:bit by means of flying leads or a short length of three-core cable. The solid-state relay module is linked to the micro:bit using four short jump leads. Note that the switched output circuits (connected by miniature terminal blocks) will, in most applications, be at mains supply potential and should therefore be treated with caution. If in doubt, we suggest that you seek advice from a more experienced person before attempting to connect AC mains loads to the thermostatic controller.

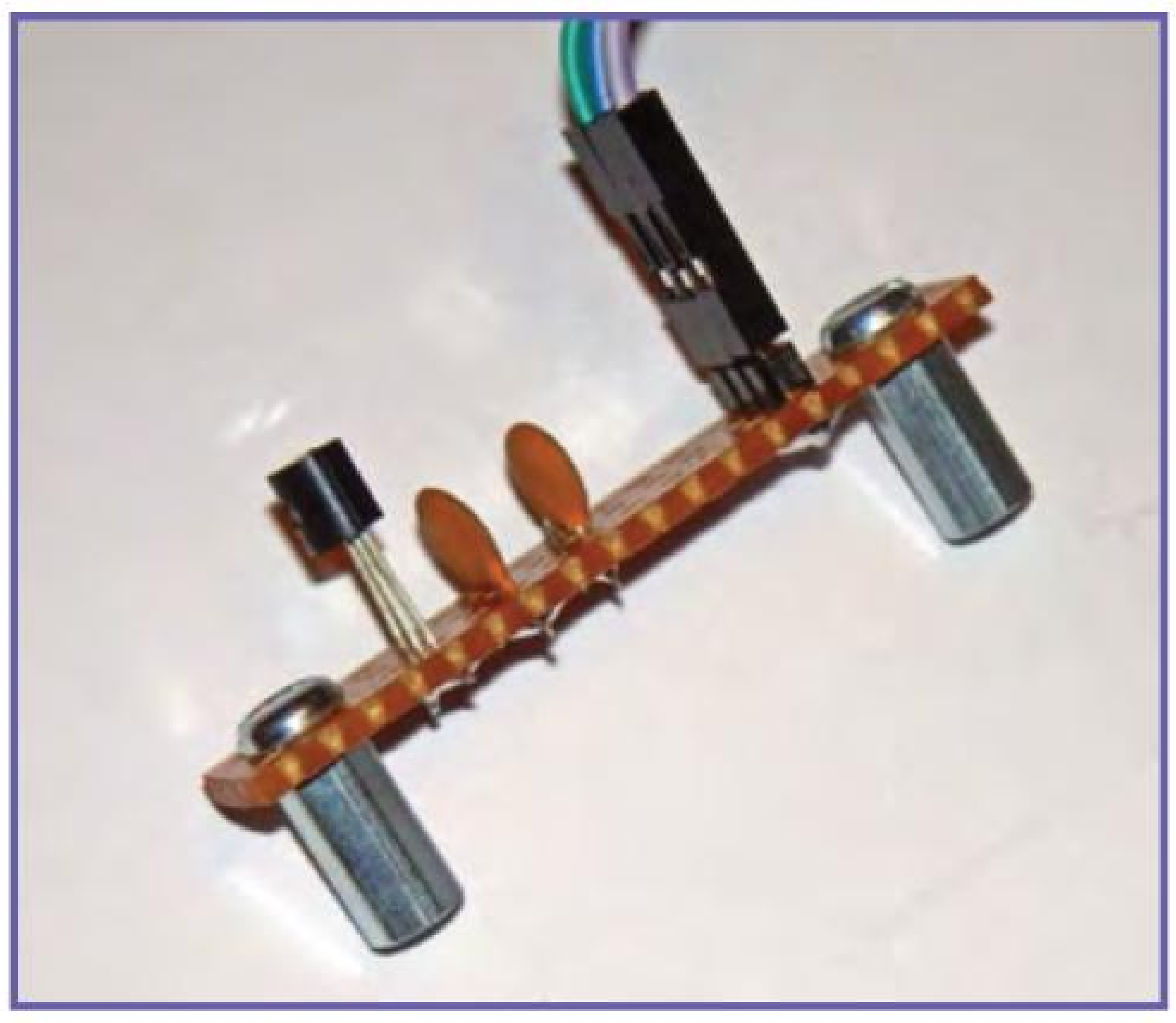


Fig.3.10. The TMP36 temperature sensor is mounted on a small piece of strip board

The two 100nF capacitors (C1 and C2) help to reduce noise, which may be a problem in some environments, particularly where stray RF signals are present and when long connecting leads are used. If this isn't likely to affect your application and you are using connecting leads of less than 0.5m you can safely omit these two components. The pin connections for the TMP36 temperature sensor are shown in Fig.3.11.

Coding

The complete Micropython code for the *micro:bit Thermostatic Controller* is shown in Listing 3.4. The code aims to maintain the temperature within a fixed range (4°C to 30°C with the values used).

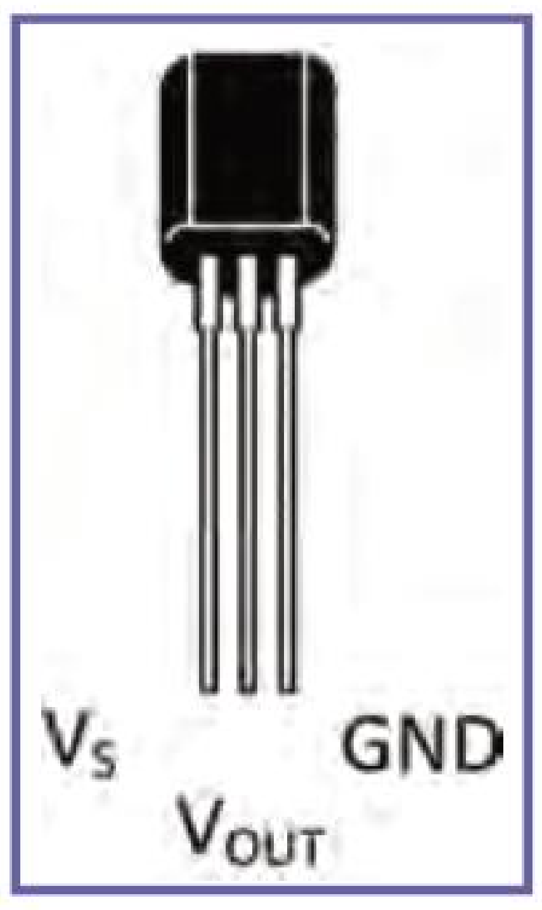


Fig.3.11. Pin connections for the TMP36 temperature sensor

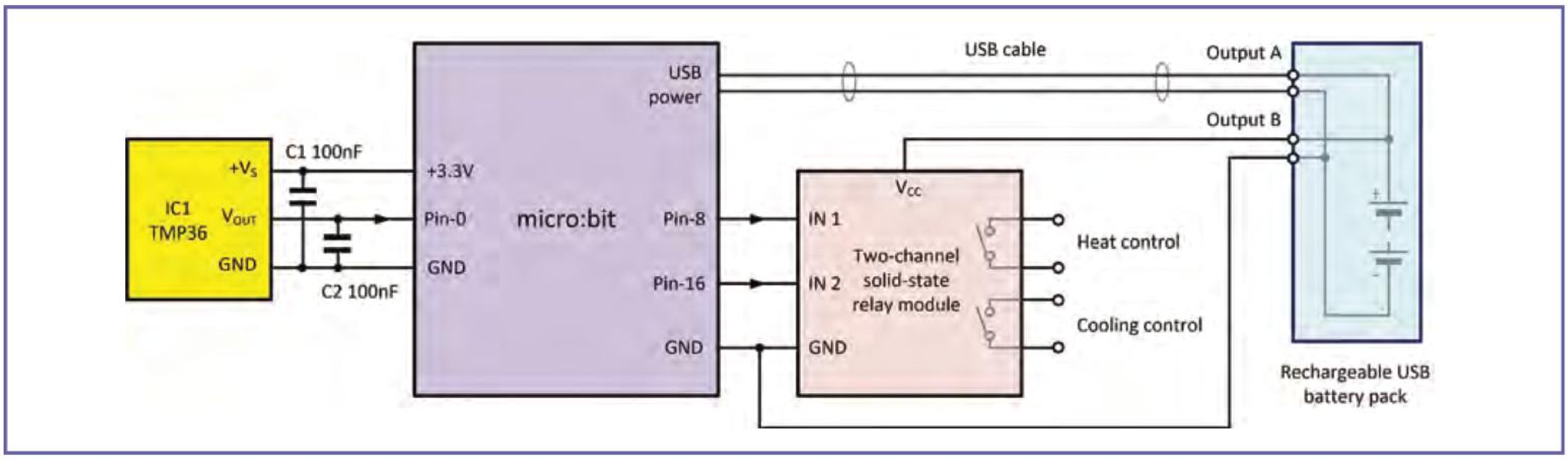


Fig.3.8. Circuit of the micro:bit thermostatic controller

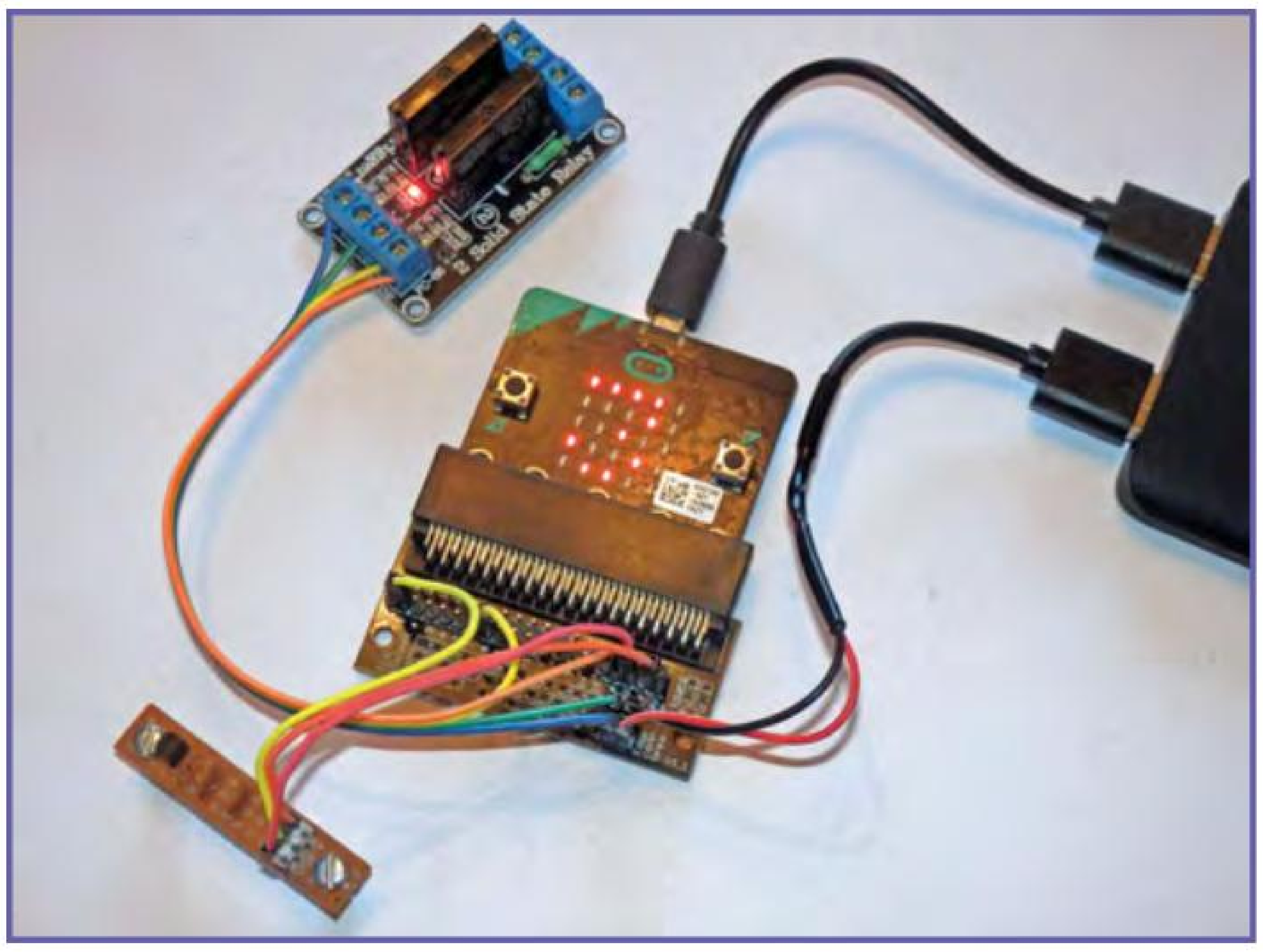


Fig.3.12. Completed micro:bit thermostatic controller

The code senses the temperature using analogue pin-0 and outputs digital control signals for the two solid-state relays using pins 8 and 16.

Pin-8 will go high for temperatures below 15°C and pin-16 will go high for temperatures above 30°C. In the first case the relay will operate and supply power to a heater, while in the second the relay will operate and supply power to open a vent or operate a fan. Note that the code assumes that the relay module is activated when its input goes high but, if the relay module uses active-low inputs, the code will need to have the 0 and 1 states interchanged in the `write_digital()` statements. Note also, that the two threshold temperatures can be easily changed to your own values. In addition, the code provides the user with a brief visual display of the sensed temperature as well as icons representing the states; 'normal, 'cooling' and 'heating'. It is well worth going the extra mile to understand this code as it incorporates a number of useful coding techniques.

What does the code do?

The `while True` statement ensures that the program continues in an infinite loop for as long as power is applied to the micro:bit. We first read the data from the temperature sensor and convert this to a value in Celsius that can be sent to the LED matrix display. Next, we check to see if the value is within the set range by first comparing it with the lower threshold value (`lower_limit`) and then comparing it with the upper threshold value (`upper_limit`) . Note that these two values are defined at the start of the code so that they can be easily changed.

First we check the lower temperature threshold. If the sensed temperature is less than `lower_limit` then pin-8 is taken high by means of a `digital-write()` statement. This then activates the heater control relay and sends an icon to the LED matrix display to indicate the heater is in operation. Conversely, if the temperature is greater than `lower_limit` then pin-8 is taken low by means of a `digital-write()` statement. This then deactivates the heater control relay and sends an icon to the LED matrix display to indicate normal operation.

Next, we check the upper temperature threshold. If the sensed temperature is greater than `upper_limit` then pin-16 is taken high by means of a `digital-write()` statement. This then activates the cooling control relay and sends an icon to the LED matrix display to indicate that cooling is in progress. Conversely, if the temperature is less than than `upper_limit` then pin-16 is taken low by means of a `digital-write()` statement. This then deactivates the cooling control relay and sends an icon to the LED matrix display to once again indicate normal operation.

Listing 3.4 Code for the micro:bit thermostatic controller

```
from microbit import *

# Set the upper and lower thresholds
upper_limit = 30
lower_limit = 4

# Define icons for the display
norm = Image("00000:"
             "00000:"
             "00900:"
             "00000:"
             "00000:")
cool = Image("99999:"
             "07070:"
             "50505:"
             "03030:"
             "10101:")
heat = Image("01010:"
             "30303:"
             "05050:"
             "70707:"
             "99999:")

while True:
    # First read the TMP36 and convert to deg.C
    sensor_data = pin0.read_analog()
    # Controller can be calibrated here (see text)
    millivolt_data = sensor_data * (3170 / 1023)
    temp_c = int((millivolt_data - 500)/10)
    display.show(str(temp_c))
    # Briefly display the temperature in deg.C
    sleep(1000)
    # Now check to see if limits are exceeded
    if temp_c < lower_limit:
        pin8.write_digital(1)
        display.show(heat)
    else:
        pin8.write_digital(0)
        display.show(norm)
    if temp_c > upper_limit:
        pin16.write_digital(1)
        display.show(cool)
    else:
        pin16.write_digital(0)
        display.show(norm)
    # Hold the display for a short time
    sleep(2500)
```

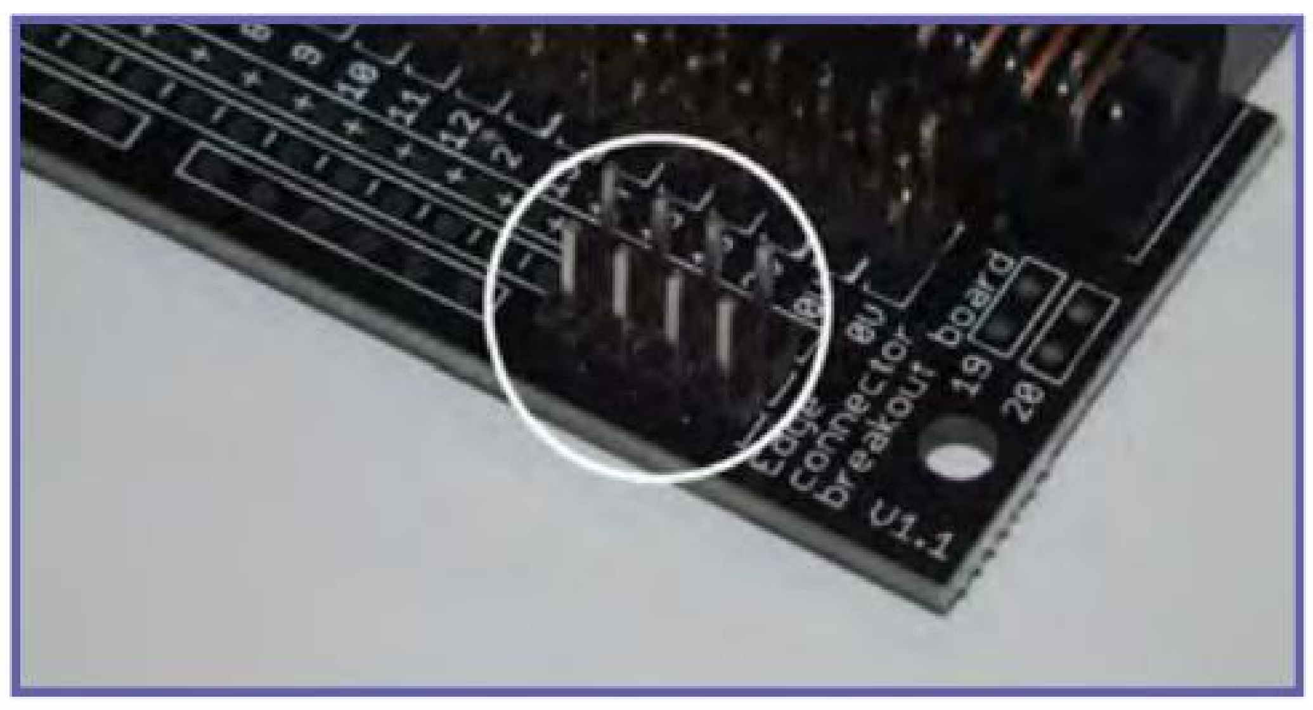


Fig.3.13. Additional pins fitted to the edge connector interface in order to facilitate a 5V supply for the solid-state relay module (see Part 2 for further information)

Testing and calibration

Enter your code into Mu and save it with an appropriate filename before compiling and downloading it to your micro:bit using Mu's Flash button (see Part 2). As the file is being sent to the micro:bit you should notice the micro:bit's power LED flashing. When this stops, the file transfer will be complete and the code should be running on the micro:bit.

The value used in the millivolt conversion (see Listing 3.4) should be the reference voltage for the micro:bit's ADC. Since this is the supply voltage (nominally 3.3V) the value could just be set as 3300 – but, for greater accuracy, you can measure the supply voltage and use this value instead. We measured our supply as 3.17V, so we entered the millivolt value as 3170mV. This value can also be changed in the event that you might need to calibrate the unit against an accurate digital thermometer.

Next month

In next month's *Teach-In 2017* we will be bringing this brief *Teach-In* taster series to a conclusion with a look at micro:bit communications. Our practical project will make use of the micro:bit's inbuilt Bluetooth Low Energy (BLE) interface.

PIC n' Mix

Mike O'Keeffe

Our periodic column for PIC programming enlightenment

PICs and the PICkit 3: A beginner's guide – Part 13

HERE we are at the end of the beginner's guide. More than 12 months later and we've covered everything from turning on an LED to analogue/digital conversion, pulse-width modulation, timers, interrupts and lookup tables. We also broke it up with two small but interesting projects that used the newfound skills in different ways. The projects included a basic *LED Traffic Light* and an *LED Binary Clock.*

This month, we finish with Electrically Erasable Programmable Read Only Memory, more commonly known as 'EEPROM'. This is a type of non-volatile memory used inside the PIC microcontroller. Volatile memory is lost once the power is removed – non-volatile memory stores its contents indefinitely.

Before I continue, I recommend having a read of the previous articles in the series. It's not necessary for this article, but you will gain a greater insight into PICs and what we're trying to achieve here. You will also need the following software and hardware:

1. Purchase the PICkit 3 Low Pin Count Demo Board (**http://tinyurl.com/h2jj2ek**)
2. Purchase the PICkit 3 Programmer + USB Cable (**http://tinyurl.com/zcpx3le**)
3. Download *PICkit 3 Starter Kit User's Guide* (**http://tinyurl.com/jyqfeuk**)
4. Download MPLAB X IDE (**http://tinyurl.com/hmehqja**)
5. Download XC8 Compiler (**http://tinyurl.com/h5g9k5l**)
6. Download Example code for PICKit3 Starter Kit (**http://tinyurl.com/z2dm5k3**)

Memory

We've touched on the various memory types inside the PIC microcontroller in previous articles. This month, we'll take a closer look at the three main memory types. For greater insight into the workings of the memory inside the PIC16F1829, I recommend reading the datasheet online (**https://tinyurl.com/ya3as3ho**). (Each of these memory types differ in detail from PIC to PIC, but the details are covered in their relevant datasheets.)

The PIC16F1829 has three types of memory: Data Memory, Program Memory and Data EEPROM Memory. The Data Memory contains 4096 bytes of SRAM memory, the Program Memory contains 8K words of Flash memory and the Data EEPROM Memory contains 256 bytes. We know a bit is a 0 or a 1 and a byte contains 8 bits, but a word can differ between various microcontrollers, which we'll cover further on.

Data Memory

The Data Memory is an SRAM memory type (Static Random Access Memory), which stores all the variables intialised during the code execution. This memory needs power to store its values. Once power is removed, anything stored in the SRAM will disappear.

The 'random' part of SRAM is a bit of a misnomer. It's called 'random', as any memory address can be accessed directly (as if by random). The idea being you could access one area of memory, followed by another area of memory, which could be stored anywhere in the device and not in any specific sequence. Early (now obsolete) memory storage devices like tapes used circulating memory, which meant if you wanted a byte of memory in the middle of the tape, you would have to start at one end of the tape and spool through to the location you wanted. This sequential method was painfully slow.

The Data Memory also stores the Core Registers, Special Function Registers, General Purpose Registers, Common RAM, Device Memory Maps and Special Functions Registers Summary. The Special Function Registers (SFR) control the operation of the device, like the peripheral and core functions, while the General Purpose Registers (GPR) contain the general area for data storage and scratch pad operations.

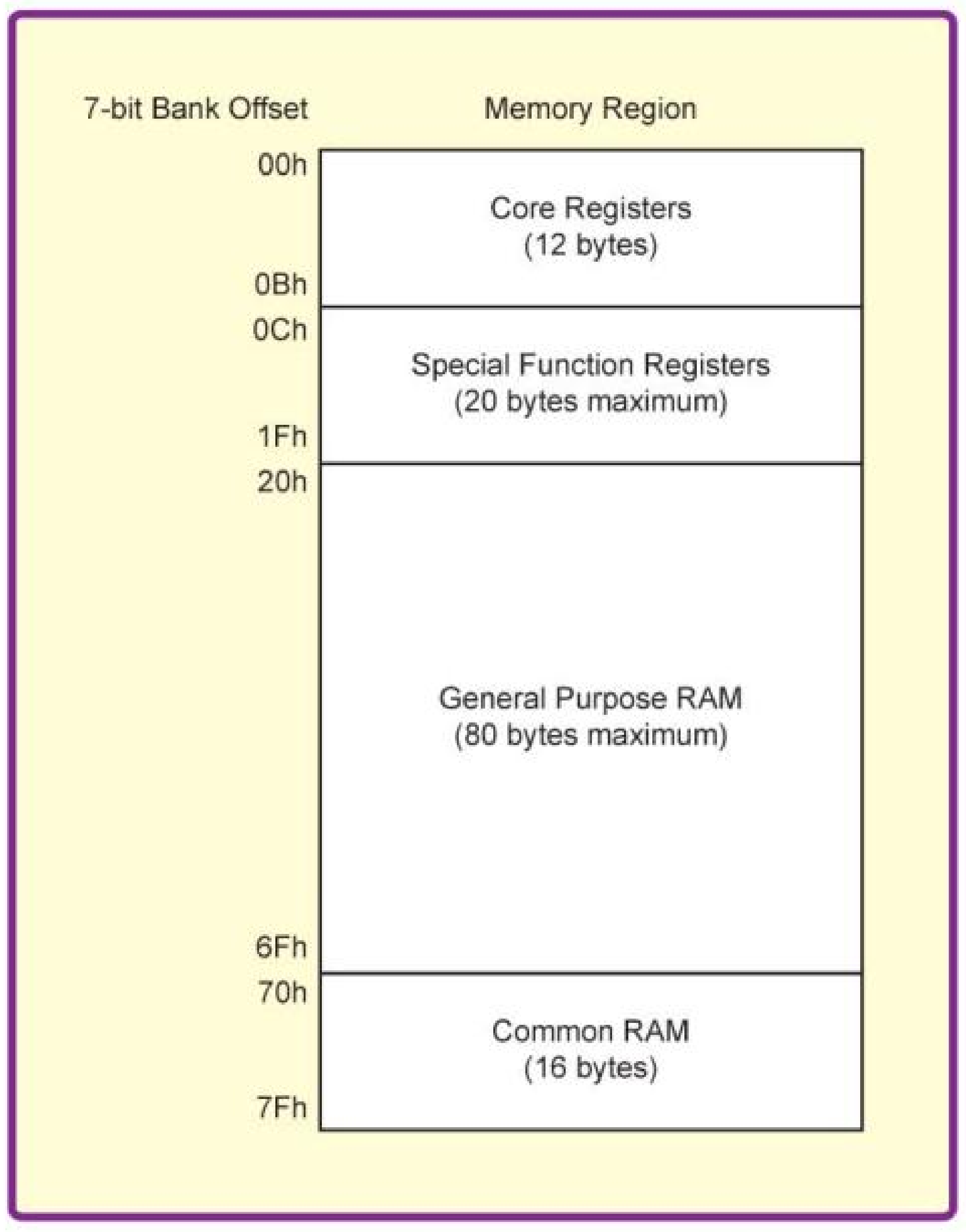


Fig.1. Banked memory partitioning

The Data Memory is partitioned into 32 memory banks with 128 bytes in each bank. The use of these 'banks' allows easy access to a larger amount of memory. As the PIC16F1829 is an 8-bit microcontroller, the addressing is limited to 8 bits, which would mean a maximum of 256 bytes of memory without the use of banks. Using these memory banks allows access up to 4096 bytes of data memory. DDR memory in PC's and laptops use this bank method as well.

See Fig.1 for the breakdown of just one of the 32 memory banks. Each bank consists of 12 core registers, 20 special function registers (SFR), up to 80 bytes of General Purpose RAM (GPR) and 16 bytes of common RAM.

Page 30 of the *PICkit 3 Starter Kit User's Guide* shows the memory map for the first eight banks. As you can see there's a lot in there. Take a good look and see which registers are familiar from the previous lessons in this series, for example: PORTA, TRISA, TMR0, PR2, ADCON9, CCPR1L, IOCAP and IOCAF.

Program Memory

The Program Memory contains the program, which we've written in MPLAB X and then programmed into our device. The Program Counter keeps track of the program execution by holding the address of the current instruction. The PIC executes each stored command sequentially by incrementing the program counter and executing the instruction at that address.

The PIC16F1829 has an enhanced mid-range core with a 15-bit program counter, which can address 32K x 14 program memory space. The Program Memory is Flash memory, which is organised differently to the EEPROM and Data Memory discussed earlier. It is partitioned into four pages of 8,192 words each. 'Pages' instead of 'banks' are used in Flash memory because they are designed for writing the program into them, whereas banks are designed for specific byte access like registers. Pages are arranged into 'rows', which are also known as 'words' and are the minimum block size that can be erased by user software. They are 14 bits long.

Each time the program starts, it starts at address 0000h, which is the Reset Vector. A jump to this address is a simple software reset. This is done by setting the Program Counter to 0000h. When an interrupt occurs, the Program Counter is forced to address 0004h, which is the Interrupt Vector Address. This means the following rows after 0004h incorporate the code for the ISR (interrupt, as mentioned in Lesson 10). The last program memory address is 7FFFh, which works out as 32,768 memory locations in total. See Fig.2 for a better idea of what it looks like. Note the locations of the Program Counter (PC), Reset Vector, Interrupt Vector and the four Program Memory pages.

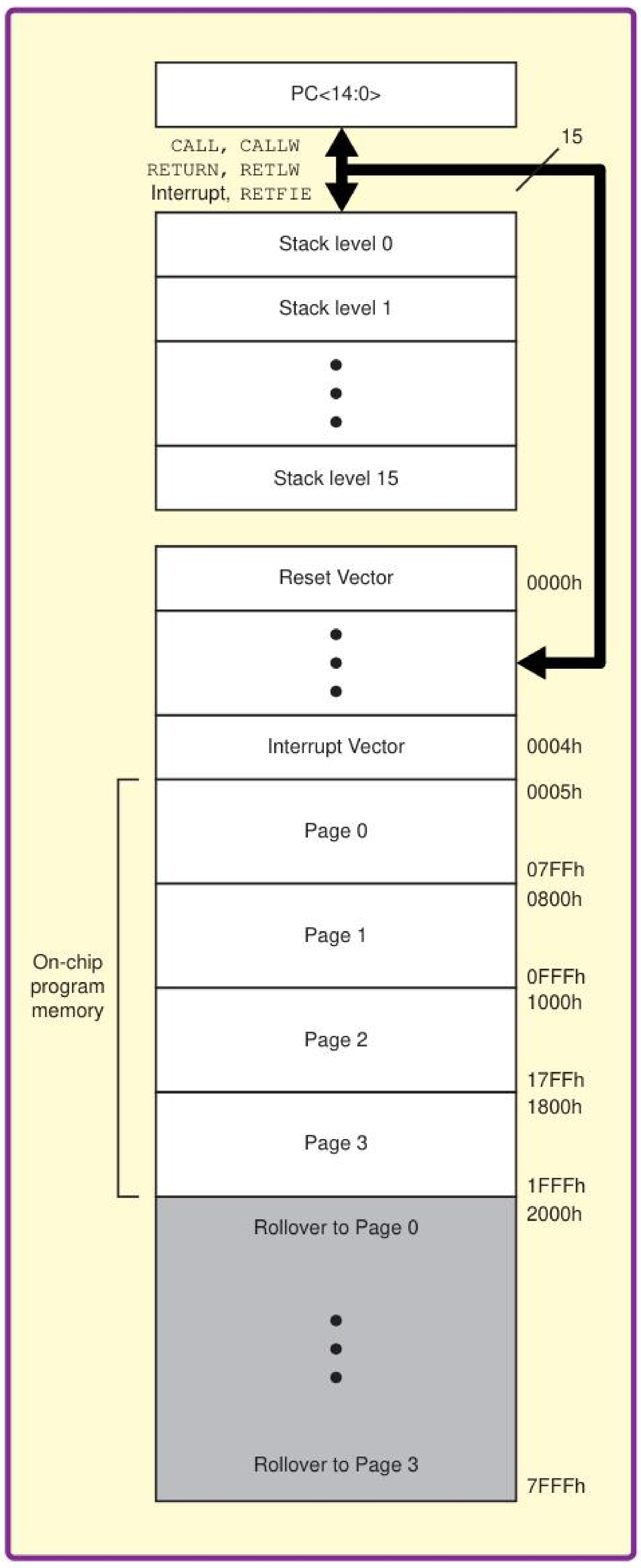


Fig.2. Program memory map and stack for PIC16F1829

EEPROM

Let's return to Data EEPROM. This is mainly used to store variables and data captured during runtime that we don't want to lose through a possible power failure. Access can be a little slower, we can only read or write one byte at a time.

The write time is controlled by an on-chip timer. Write/erase voltages are needed and generated by an internal charge pump rated to operate over the voltage range of the device for byte or word operations. This is important to note as it can add unwanted delays in program execution or read and write errors.

Unlike the Data and Program memory, the EEPROM does not have any specific memory mapping and is indirectly addressed through the special functions register instead. The address spans from 00h to FFh, which is 256 bytes.

The code

The example code for the PICKit 3 Starter Kit for EEPROMs uses the button to save the LED pattern derived from the ADC input from the Potentiometer. Power can then be disconnected and once reconnected will display the saved LED pattern. It's a powerful, yet simple example demonstrating the non-volatile nature of the EEPROM. The code uses two new functions we haven't seen before: `eeprom_read(<addr>)` and `eeprom_write(<addr>,<value>)`.

```
#include <htc.h>
#define _XTAL_FREQ 500000

#define DOWN 0
#define UP   1
#define SWITCH   PORTAbits.RA2
```

As usual, the code starts off with the **include** and **define**. The code snippet above sets the clock frequency to 500kHz. Then we define three constants to be used through our code, `DOWN`, `UP` and `SWITCH`. We've seen **define** taking a value before, but here we have the `SWITCH` definition taking the state of the pin A2. This is basically taking PORTA**bits**.RA2 and swapping it for `SWITCH`, which makes the code more user friendly.

```
unsigned char adc(void);
```

Here the function prototype **adc** takes no value and returns an **unsigned char**.

```
void main(void) {
     OSCCON = 0b00111000;
     TRISC = 0;
     LATC = 0;
```

These next two lines, we've seen many times before. We set the clock to 500kHz using the OSCCON register and we set Port C to outputs using the TRIS register. Then we latch the outputs of Port C all to zero.

```
TRISAbits.TRISA2 = 1;
ANSELAbits.ANSA2 = 0;
```

These two lines of code take input A2 on the PIC and set it up as a digital input. A2 is connected to the button on the Low Pin Count Demo board. This will be used to save the output on the potentiometer to the EEPROM.

```
TRISAbits.TRISA4 = 1;
ANSELAbits.ANSA4 = 1;
ADCON0 = 0b00001101;
ADCON1 = 0b00010000;
```

Nothing new in these next four lines. Port RA4 is connected to the output of the potentiometer on the Low Pin Count board, so we set it to an analogue input. Port RA4 is then set up as the source of the ADC and the ADC module is enabled using the ADCON0 register. ADCON1 then sets the returned values to be left justified, the speed is set to FOSC/8 and the Vref is VDD. This is all covered in previous lessons.

```
INTCONbits.IOCIE = 1;
IOCANbits.IOCAN2 = 1;
INTCONbits.GIE = 1;
```

The next three lines of code focus on setting up the interrupt. INTCON**bits**.IOCIE is the Interrupt-on-change enable bit. The IOCAN**bits**.IOCAN2 selects which input we want the interrupt to detect a change on. In this case, it's Port A and input A2. We've already set up this pin as a digital input earlier. INTCON**bits**.GIE is the global interrupt enable, which enables all interrupts.

```
while (1) {
     LATC = eeprom_read(0x00);
     SLEEP();
}
}
```

This is a new piece of code. The interrupt has been setup and will run into this **while** loop. There are two commands most commonly used to communicate with the EEPROM. These are simply read and write. For a read, all we need to know is from what address we want to read from. To write, we need to know what address and what value we want to write to that address. **eeprom_read(0x00)** will read from the address 0x00 in the EEPROM and write the output to Port C, which is where our LEDs are connected.

The SLEEP function is a commonly used function, which is recognised by the compiler. It doesn't need to be specified like other functions. It puts the PIC in a deep sleep, which turns off the internal oscillator and can reduce current consumption to below 5µA. The PIC can now only be woken through a power cycle or by pressing the button and activating the interrupt on change input.

```
unsigned char adc(void) {
     __delay_us(5);
     GO = 1;
     while (GO) continue;
     return ADRESH;
}
```

We've seen our final function **adc** many times in previous lessons. There's a 5µs delay to allow the capacitor on the ADC pin to charge before starting the conversion by setting the GO command to 1. Then we wait for the conversion to complete and return the eight most-significant bits, which are stored in the ADRESH register.

```
void interrupt ISR(void) {
    unsigned char adc_value = 0;

    if (IOCAF) {
        IOCAF = 0;
        __delay_ms(5);
        if (SWITCH == DOWN) {
            adc_value = adc();
            adc_value >>= 4;
            LATC = adc_value;
            eeprom_write(0x00, adc_value);
        }
    }
}
```

We've looked at interrupts previously in *Lesson 10* of the *Beginner's guide*. The code is very similar here. When a change is seen on input A2, through the button, the PIC is woken up and this ISR is then serviced. In this ISR, we initialise a local variable `adc_value` and set it to 0. The only interrupt that is checked here is the `IOCAF`, which is the interrupt-on-change for Port A flag. So if any pin on Port A changes, this flag will be set. In the code, we first check to see if this flag has been set, if it has then it must be reset. Then there is a small 5μs delay to account for button debounce, which was discussed back in Lesson 6. The next thing the code checks for is if the switch is down. The pin A2 is pulled up through a series resistor to the onboard voltage. When the button is pressed, the pin will go low, activating the interrupt. Then we check the state of the `SWITCH`. If it is down, we capture the ADC value from the potentiometer, right shift it by four and store in Port C (our LEDs). Next we have our second function use of the EEPROM; `eeprom_write(0x00, adc_value)`, which writes the ADC value to the first address in the EEPROM.

Once the code has been compiled and programmed onto the Low Pin Count Demo Board, we can see how it behaves. Press the button to take the value of the potentiometer and store it in the LEDs. Notice how moving the potentiometer doesn't incur a change on the LEDs, but pressing the button will store this change. It should be possible now to power cycle the Demo Board and see that the LEDs stay the same before and after, regardless of the state of the potentiometer.

Next month

We finally bid *adieu* to the *Beginner's guide* with next month's project. The goal is to use as much from the 13 lessons as we possibly can, as well as some other design techniques to design and build an interesting project.

Not all of Mike's technology tinkering and discussion makes it to print.

You can follow the rest of it on Twitter at *@MikePOKeeffe*, up on *EPE Chat Zone* as *mikepokeeffe* and from his blog at *mikepokeeffe.blogspot.com*

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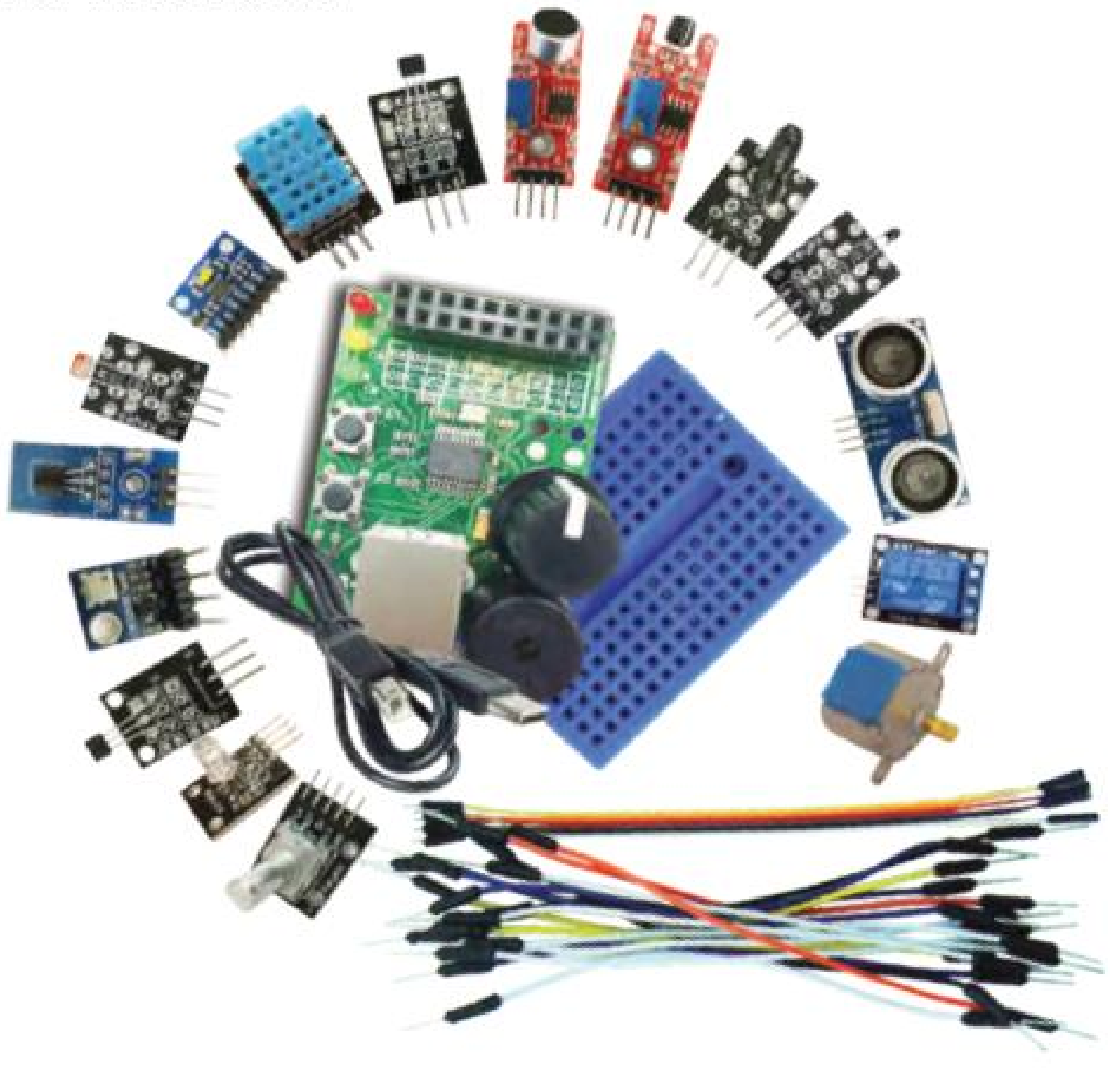

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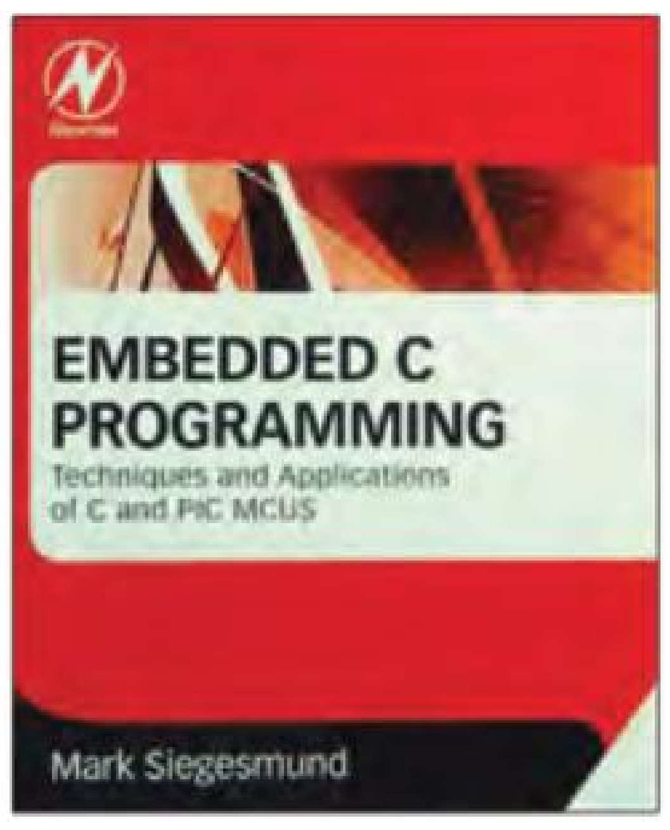
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NET WORK

by Alan Winstanley

Enough to wanna cry

BRITAIN recently suffered the serious consequences of two major IT outages, the first in May 2017 when WannaCrypt ransomware spread like wildfire across a number of National Health Service systems and brought them crashing to a halt. This terrible crime was blamed on powerful software allegedly stolen from America's National Security Agency, which was then hacked before being unleashed back into the wild. The attack blocked access to clinical records, caused countless medical operations to be cancelled in Britain's hospitals, entire departments to close briefly and high-tech equipment to be left standing idle while medics struggled with pen and paper, as IT staff fought tirelessly to restore data from backups.

A lot of blame was shouldered by legacy Windows XP on some NHS computer systems, and it was not the first time this problem had hit the health service: late last year a family member's operation was cancelled at very short notice due to a similar emergency caused by ransomware. Almost every version of Windows could be vulnerable to this particular exploit though, and Microsoft had already issued a patch even for systems no longer officially supported. Highly-detailed analysis and advice for Windows users on how to avoid WannaCrypt is on Microsoft's TechNet blog, see **http://tinyurl.com/llq3b58**. Official advice is not to pay ransoms as it simply encourages more of the same, and there is no guarantee that you will get your data back anyway.

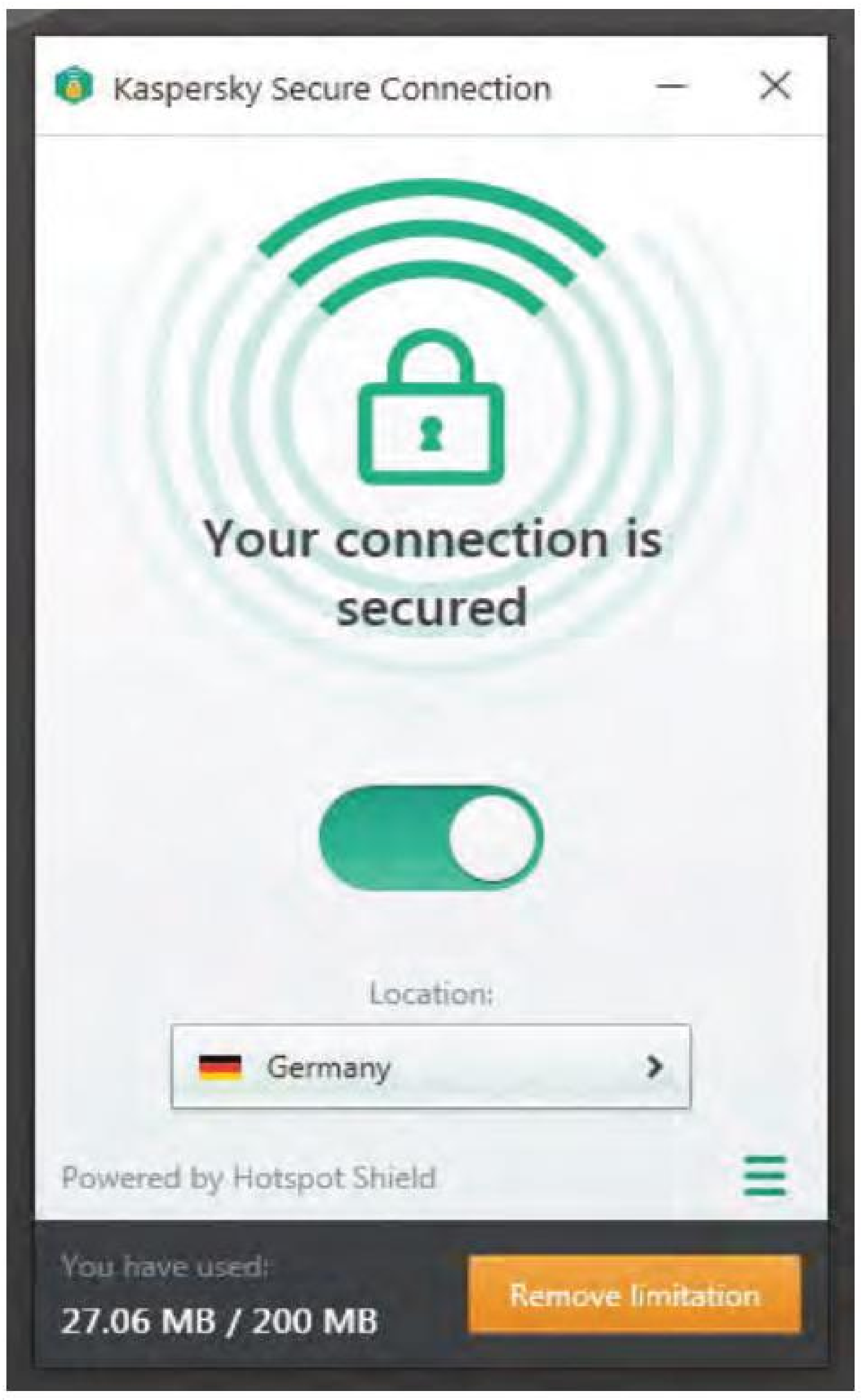
The second major IT catastrophe hit London's major airports in May when a loss of IT systems, initially blamed on a British Airways data centre power problem, grounded hundreds of BA flights and left tens of thousands of travellers stuck at the airports for days with no luggage. Passengers with the airline were pointed towards the British Airways website for advice, but that was down as well. This debacle is only matched by one at London's Gatwick airport in 2013 due to another power outage when the North terminal's electricity sub-station was flooded!

These kinds of problem will only get worse as we become increasingly wedded to the use of IT, networking, databases, smart Internet-of-things (IoT) devices, smart meters and every other type of networked technology. There is no doubt that you only have to blink for a moment and some form of exploit or other can find its way into a system, perhaps through a carelessly-clicked email attachment, an infected USB stick or by checking a phony website. It's best to leave nothing to chance and keep a *physical backup* of data on a *separate removable disk drive* – ransomware such as CryptoFortress can spread silently through network 'shares' even if they are not mapped to a drive letter, so you might want to back up your data periodically to a USB drive, unplug it and keep it safe.

Hardware and cloud-based devices such as the Bitdefender BOX claims to safeguard all networked devices against attack, including domestic IoT gadgets: an updated Version 2 of the hardware Bitdefender BOX is due this summer.

Virtual private network

In last month's *Net Work* I mentioned how, following some local area network problems, as a last-gasp solution I replaced Avast Anti-Virus with Kaspersky Internet Security and my work immediately started flowing once again. The Kaspersky suite includes software tools both for enthusiasts and everyday users, but the program's myriad options take time to master and can create problems of their own in the meantime. One of them is its 'Safe Money' protected web browser, which it claims will handle e-commerce transactions more securely. Unfortunately, I soon found myself disabling it altogether. Just a few minutes ago, for example, the consumer Tassimo drinks website stalled at the secure payment page because Kaspersky Safe Money was silently blocking the checkout phase, a problem I later found was mentioned in Tassimo's online FAQ. As a result, my online order got duplicated and stuck as 'pending', so I had to phone them instead.



Your connection is secured

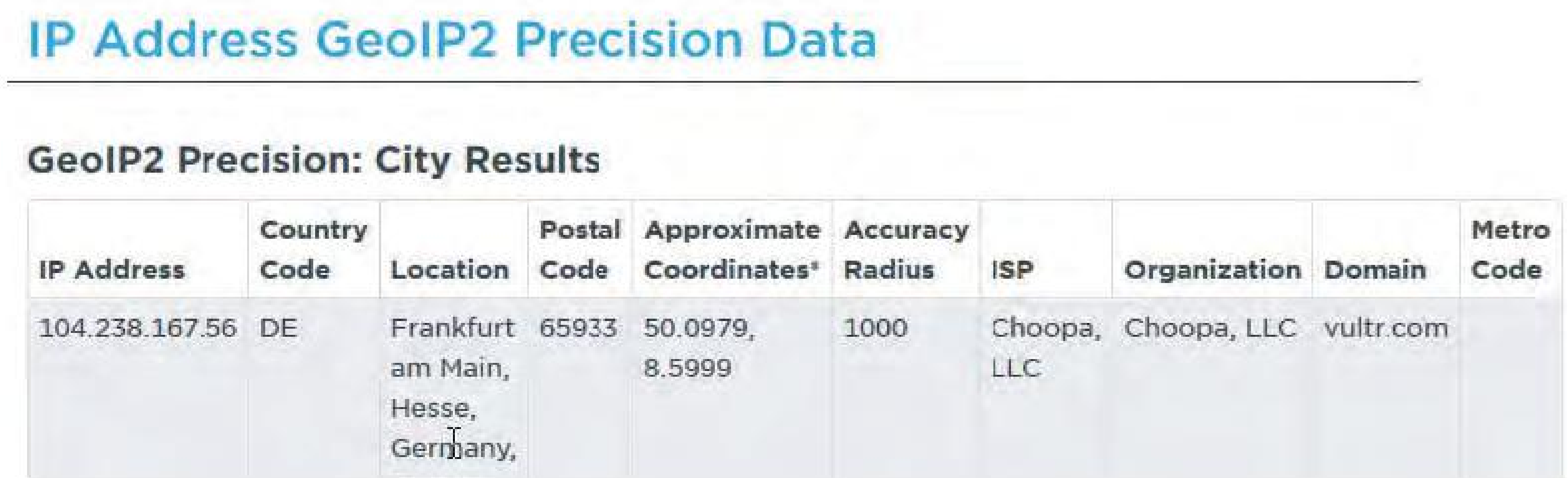
Location: Germany

You have used: 27.06 MB / 200 MB

Kaspersky Secure Connection is a free VPN with limitations on traffic and remote server locations

Another tool Kaspersky offers is 'Secure Connection', their virtual private network (VPN) service. As readers know, users each have a unique IP address provided by their ISP; a remote web server typically logs the fact that your IP address visited a particular web page address. Other information, including the type of web browser or operating system, can be gleaned from a visit, though it's not always very accurate. Your approximate location can be determined as well, using geo-location systems that are often used to prevent fraud, but can also be used to target you with localised adverts or prevent you from accessing content (see later). One geo-IP industry specialist is Maxmind (**www.maxmind.com**). Of course, many web pages also load cookies onto your machine to help improve your 'online experience' as they put it: cookies may contain your IP address for future reference, but they don't capture personal details.

A VPN such as Kaspersky Secure Connection or Avast SecureLine VPN is a private, encrypted 'pipeline' through which you can surf the Internet using a secure third-party network. This disguises your own IP address and location, and makes it appear like you're using an IP address (and location) supplied by the VPN instead. The VPN may route its service via any number of overseas countries, but if you want the luxury of choosing a particular country yourself you may have to subscribe to a paid-for VPN service rather than a free one. Also, network traffic will often be metered, which limits the volume that can be carried this way. Kaspersky's free service, for example, sends you via Germany by default, allowing 200MB of traffic, but you can pay extra to choose from a list of other countries if you want. As proof, having enabled my free Secure Connection using Kaspersky, I found Google searches went straight to google.de. You can view your IP address at **www.ipchicken.com** and get more details of your VPN location from the Maxmind website, which reckons I'm in Frankfurt at the moment.


IP Address GeoIP2 Precision Data

GeoIP2 Precision: City Results

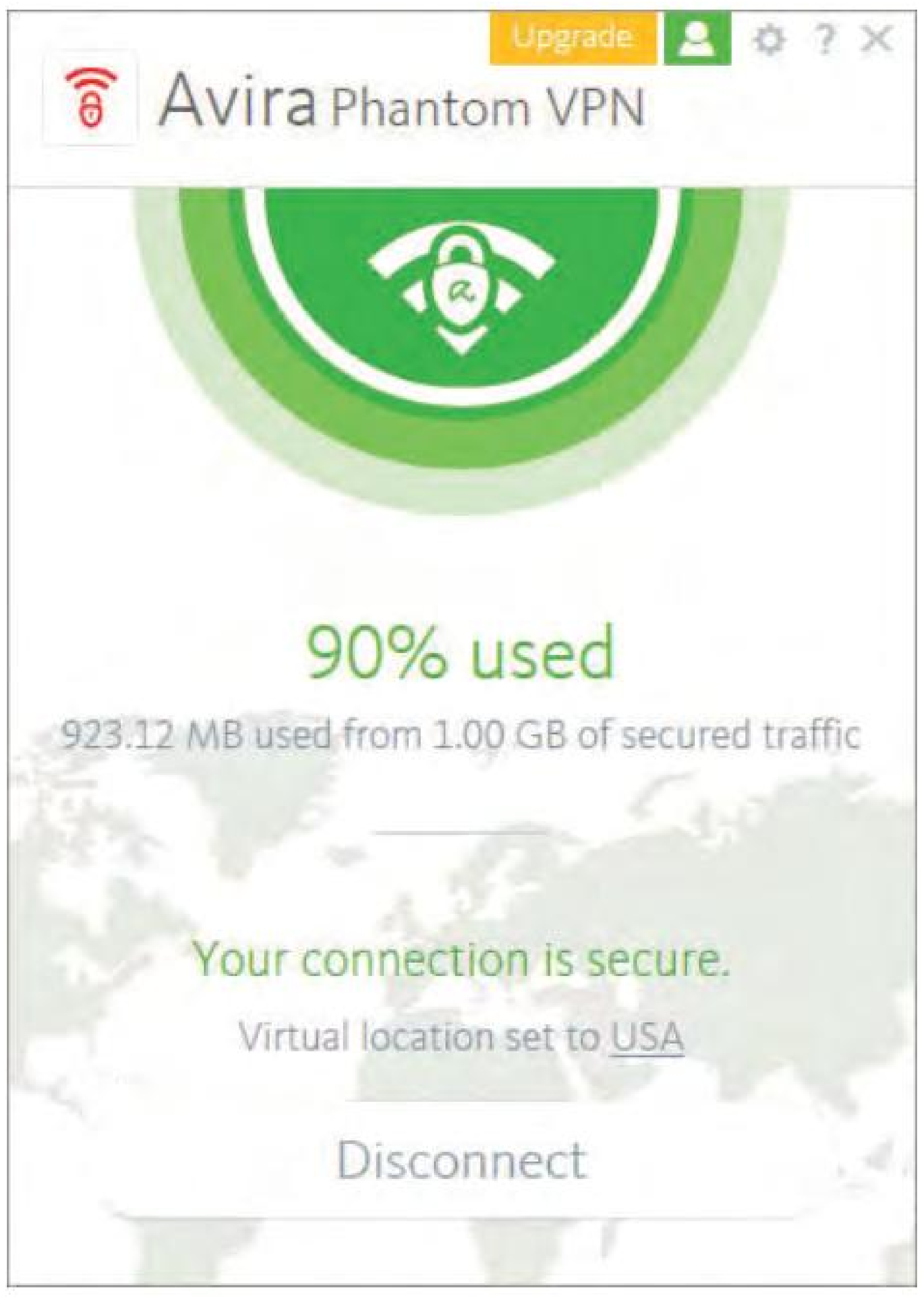
IP Address	Country Code	Location	Postal Code	Approximate Coordinates*	Accuracy Radius	ISP	Organization	Domain	Metro Code
104.238.167.56	DE	Frankfurt am Main, Hesse, Germany,	65933	50.0979, 8.5999	1000	Choopa, LLC	Choopa, LLC	vultr.com	

After connecting through a VPN, a check on ***Maxmind.com*** *confirms the author's IP is now based in Germany*

Less public, more private

The data encryption of a VPN can also help protect you when using public Wi-Fi hotspots. Mobile users can't always know who is behind a hotspot: is it owned by a local authority, or is a fraudster lurking nearby? Whoever controls the hotspot's router has control over the connection, which can ultimately lead to theft of logins, account hacking and online fraud or identity theft. One way of preventing eavesdropping on a network that you don't control is to log in via a VPN service in the first place.

Other free VPNs include Avira Phantom VPN from **www.avira.com/en/avira-phantom-vpn**, which grants users a wider choice of countries, compared with Kaspersky, plus 1GB of traffic. Like other VPNs, Avira Phantom VPN claims to 'safeguard your private data' but after installing it something curious, and not a little irritating, was gradually noticed when surfing around: a price comparison banner pop-up would open in Firefox offering best prices and special offers. It looked just like malware spying on my traffic and some Malwarebytes scans, Adware scans, and plenty of googling around proved fruitless.



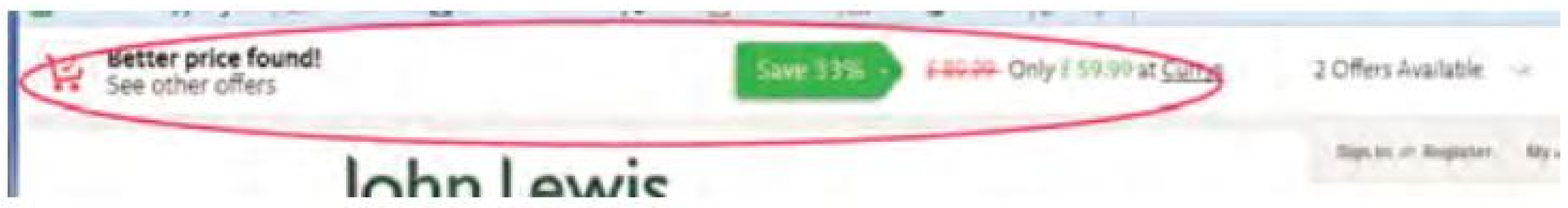
90% used

923.12 MB used from 1.00 GB of secured traffic

Your connection is secure.

Virtual location set to USA

Avira Phantom VPN offers 1GB free and a wider choice of countries



The price comparison tool enabled by default when Avira Phantom VPN is installed. It monitors your online shopping and claims to offer deals from 'safe websites only'

Eventually, the cause was tracked down to none other than Avira itself, as an 'Avira Browser Safety' add-on appeared in Firefox (Chrome users have the same issue) after installing Avira Phantom VPN. By disabling it, nuisance price comparison pop-ups were halted, presumably disabling the browser safety (landing on dodgy websites) feature as well. After digging deeper in my web browser, a Price Comparisons switch was de-selected in Avira's toolbar Options and normality returned to my busy desktop. Who would have thought it? Avira states in an Aha! pop-up that the tool only brings you better deals from 'safe websites'.

Smarter DNS

Overseas readers may not know that in Britain a £147/ $180 annual TV licence is needed to view live TV broadcasts (whether BBC or commercial TV) on any apparatus, but the advent of streaming media made a mockery of the rules. British customers now need a TV Licence to download or watch BBC programmes on iPlayer as well, whether live TV, catch-up or on demand. Consequently, the BBC is notorious for blocking access based on a user's location and Brits abroad, who own a TV licence, still can't view it!

Numerous websites restrict their rights-managed contents to visitors from the same country, especially for viewing online TV channels or movies. In theory, a VPN can fool media sites into believing that you reside in that country instead, allowing you to access foreign content from home. Conversely, you may be abroad on holiday or business and wish to check, say, BBC iPlayer from overseas, so a suitable VPN should let you view it like you were back home in Britain. This idea is more frustrating than it sounds and you can expect obstacles all the way. Access through a VPN can be a very hit and miss affair and it may be necessary to subscribe to a service like ExpressVPN (**www.expressvpn.com**) which claims to have servers in nearly 100 countries, but costs almost $100 a year.

An alternative to a VPN for watching media online is a Smart DNS service like Unlocator, (**https://unlocator.com/**) which is optimised for handling streaming media channels. While it lacks the end-to-end encryption of a VPN, its sole job is to hide your physical location from any geo-IP detection systems and it may prove faster too, so you watch online media seamlessly or surf anywhere else 'as normal'. Unlocator costs $5 a month and a 7-day free trial is available, with no payment details being needed up front. You must either configure the DNS on each device (home computer, media player, smartphone, games console etc.) separately or as a 'blanket measure' nail new DNS addresses into your router instead. Unlocator's online tutorials seem excellent for ordinary users, and they claim their system is safe to use as all your traffic remains untouched, and they don't retain any logs when using their DNS servers. Others include SmartDNS Proxy (**smartdnsproxy.com**) and **Overplay.Net**. Do you view TV and movie channels from overseas? Write in and share your experience and advice.

Huey Lewis and the News

It's hip to be square, as the song by Huey Lewis and the News goes, so a recent online hunt for house insurance found me at the website of none other than John Lewis, the UK store chain with a strapline of 'Never knowingly undersold'. After comparing rivals' policies very closely, a freebie offered by John Lewis helped close the deal: a £59 Philips Hue Starter Kit with two Smart LED bulbs if you sign up for their Premier package by 6 July. More details are at **www.johnlewisfinance.com/insurance.html** and I'll share the News when my Hue smartbulbs finally arrive!

You can write to me at: **alan@epemag.net**. See you next month for more *Net Work*!

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CIRCUIT SURGERY

REGULAR CLINIC

BY IAN BELL

Transmission lines and high-frequency PCB designs

THE RECENT theme in *Circuit Surgery* has been transmission lines. Our discussion started two months ago with an article on oscilloscope probes in response to a question by *EPE Chat Zone* user ***simonbond***. We saw that to understand why oscilloscope leads are designed the way they are we have to take their behaviour as transmission lines into effect – at high frequencies we cannot assume that oscilloscope leads behaves as simple wire. Last month, we looked at transmission line concepts and theory in more general terms, and in more depth than in the oscilloscope article. This month, we will look at more practical matters and the design of PCB layouts for high frequency signals. This design practice stems from an understanding of the behaviour of high frequency signals, including transmission line theory.

Transmission line theory helps us understand the phenomena which occur when the time taken for a signal to travel the length of an electrical connection (cable or PCB trace) is comparable with, or less than, the timing of the signal concerned (for example, the length of one cycle of an AC waveform or the length of a digital pulse). We saw that the speed of the signal is typically a fraction of the speed of light (from about half light speed upwards). When considering the common sizes of test leads and PCBs this typically corresponds with frequencies of tens or hundreds of MHz and up, and timescales of tens of nanoseconds or less. For waveforms other than sinewaves, the signal contains frequencies which are much higher than the fundamental frequency and this must be taken into consideration when deciding if transmission line effects may be important. For example, for fast digital circuits the duration of short pulses and rise/fall time of edges (time to change between 0 and 1 logic level) needs to be considered.

The frequency at which electronic systems operate tends to increase as technology develops. Nowadays, many ICs are readily available at low and moderate cost, which provide interesting and useful functionality at very high frequencies, and these may be the basis of projects (for example, variants of the Direct Digital Synthesis (DDS) chips discussed in *Circuit Surgery*, March 2017). This tends to make it more likely that contemporary electronics enthusiasts, other than those involved with radio who are already specifically working with RF, will encounter the need for high-frequency design techniques.

When to use transmission lines

Crudely, we can divide circuits, and their associated board design, into three categories – first, those operating at low frequencies where special high-frequency considerations are not required (although good layout practice may be needed for other reasons); second, there are the 'high-end' cases where very high-frequencies and very high-circuit performance is demanded. This would usually be the domain of professional designers and may involve approaches such as using sophisticated electromagnetic modelling tools to ensure PCB designs perform as required. In between, there is our third category, where there is a range of circuits which will definitely benefit from high-frequency design considerations for board layout, but where this can be achieved without the need for advanced tools or expensive specialist materials. By following good design practice, well-established rules of thumb and perhaps some simple calculation tools, suitable designs can be achieved.

A key concern when considering high-frequency signals on circuit boards is matching. We discussed the matching of transmission lines last month, but here is a brief recap.

Theory overview

Fig.1 shows a voltage source, with source resistance R_S connected to a load R_L via a transmission line. This could represent a single connection trace on a PCB (eg, between two ICs) or some other point-to-point connection, such as a test lead. The transmission line has a characteristic impedance, Z_0, which is independent of its length and which determines its matching requirements. Typical required values for Z_0 for PCB traces are 50Ω and 75Ω, but other values occur. Datasheets for ICs with high frequency I/O may specify trace impedance requirements.

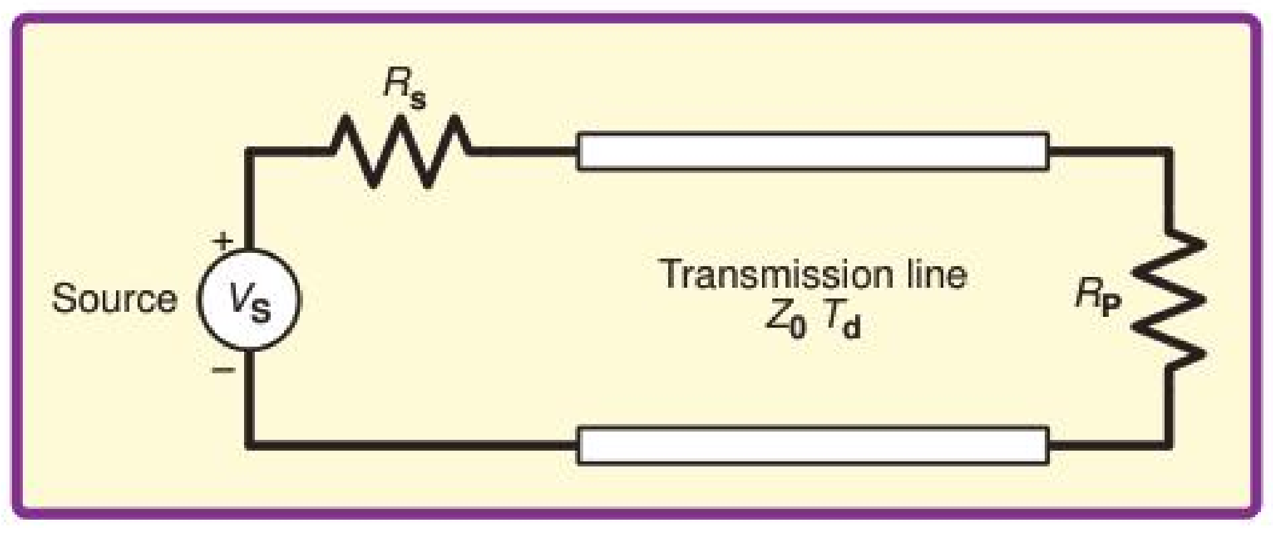


Fig.1. Transmission line with source and load resistances

We saw last month that if either, or both, the load and source impedance failed to match the transmission line characteristic impedance then signal reflections would occur at the ends of the line, causing disruption of the signal. In practical terms, achieving matching means that it may be necessary to add components (eg, 50Ω resistors – the nearest standard value is 49.9Ω) at the source and/or load ends of the connection, depending on the characteristics of the other circuitry (eg, an IC's I/O impedance). It also means that the PCB trace has to be designed to have the correct transmission line characteristic impedance. For our initial discussion we will assume a single straight trace. If the trace has a corner, or bends abruptly, or splits into multiple signal paths then the impedance may vary along it length, complicating matters. We will discuss some of these other issues later.

Before looking at impedance in more depth it is worth commenting on the time aspect of transmission line connections. In addition to Z_0, the line in Fig.1 is characterised by T_d, the propagation delay time for a signal to travel from one end of the line to another. If the time that a signal takes to travel along an interconnection is comparable with the signal timing then it follows that if you have multiple coordinated signals, such as multi-bit digital data, or differential analogue signals, then variations in connection length between the signals may cause the signals to become significantly skewed in time with respect to one another. Therefore, a rule for design of high-frequency PCBs is to keep the length of traces carrying related signals as close to equal as possible. You may see apparently convoluted paths on boards where the length of one trace had to be extended to match another. Some PCB design tools have the facility to match the length of traces where required during routing.

PCBs and transmission lines

The characteristic impedance of a PCB trace depends on the geometry of the signal trace and associated ground connections (signal return path) and the dielectric constant of the PCB material. Given that the dielectric properties, copper thickness and PCB thickness are fixed for a given board, a key parameter that can be varied by the user is the trace width. Thus, in some cases, 'designing the PCB trace to have the correct transmission line characteristic impedance' translates simply to setting the correct trace width. If you started the process of calculating the required trace width from scratch, from the basics of electromagnetic theory, there would be a lot of difficult maths involved, but fortunately many people have done this already and calculation tools for commonly used PCB geometries are readily available online.

To use these online calculators you need to provide relevant data about the PCB, which are the inputs to the calculation. Specifically, you need the PCB thickness, the thickness of the copper and the dielectric constant for the PCB material. If you purchase board to etch yourself from suppliers like RS and Farnell then the product web page or linked datasheet will specify the relevant values. Similarly, if you get your PCBs made by one of the many fabrication services, datasheets should be available on their website. For fabrication services you may get a choice of board and copper thicknesses, and possibly board material, as part of the online ordering/quotation process.

Standard PCBs use FR4 glass-reinforced epoxy laminate, which typically has a dielectric constant of 4.2 to 4.9. The datasheet may quote dielectric constant values for different frequencies, in which case you should use the most relevant value for the signal concerned. Typical PCB thickness for standard double sided boards are in the range 0.8 to 1.6 mm. Copper thickness is not always specified directly. Often, the copper 'thickness' is specified in ounces (oz) per square foot, sometimes abbreviated to just ounces. The most common value is 1 oz, but values ranges from 0.5 oz to 4 oz, with the higher values used in high-current applications. It is easy to translate from ounces (per square foot) of copper to thickness – 1 oz of copper corresponds to just under 35µm of copper thickness, so just multiplying the value in ounces by 35µm gives the thickness. PCB measurements are also sometimes expressed in mils (thousandths of an inch). 1.0 mil is 25.4µm, so 1 oz copper has a thickness of 1.37 mils.

As previously mentioned, transmission lines properties of PCB traces depend on the specific geometry of the traces. There are several commonly occurring geometries that are given specific names, and it is these names that should be used to find appropriate online calculators when designing PCBs. Three of the most common geometries for single signal traces are shown in Fig.2 to Fig.4. There are also similar geometries for two-signal traces, typically used for differential signals. This is not an exhaustive list of geometries, and several other variations can be used. Also note these figures are not to scale – the copper is shown much thicker than in reality for ease of annotation.

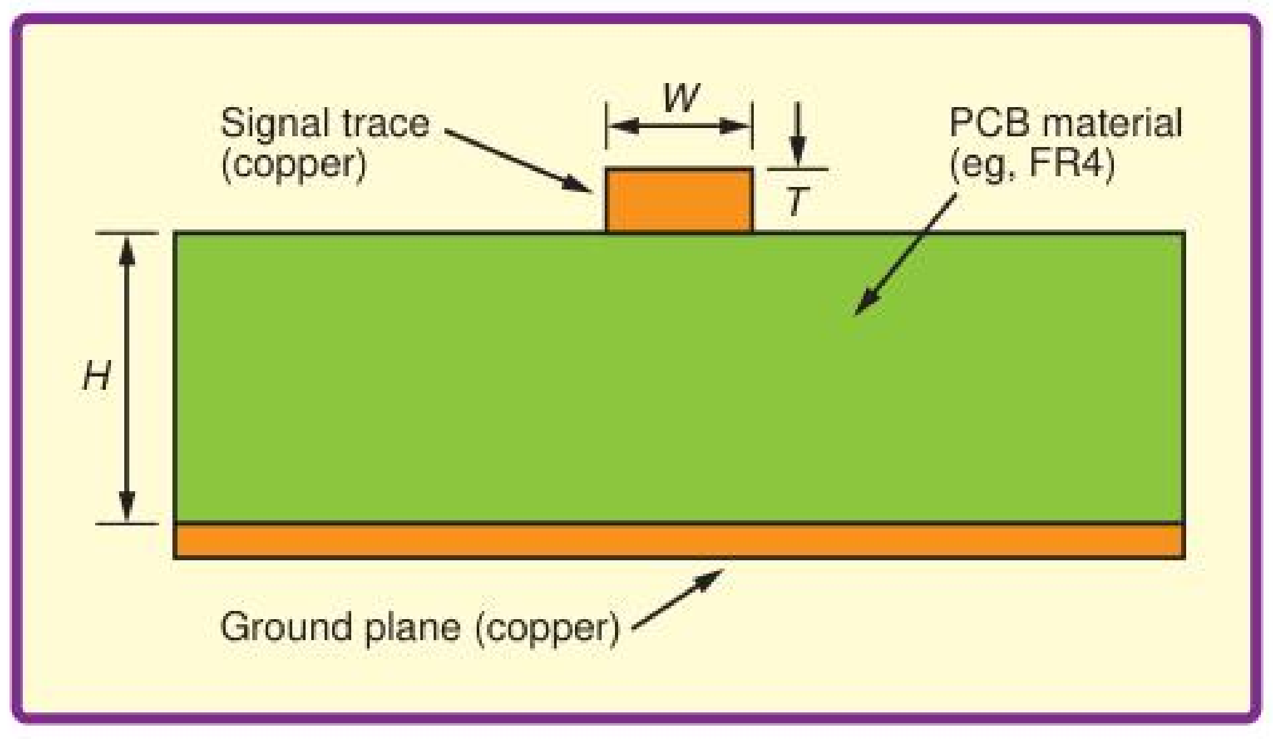


Fig.2. Cross section of a microstrip PCB trace

Microstrip

Fig.2 shows the 'microstrip' geometry. This is essentially a straight trace running across the top of a double-sided PCB without any other copper close by, and with a ground plane on the other side of the board. A ground plane is simply a large area of copper on the board that has a good connection to signal ground and which provides the return path for the signal. In PCB design tools, ground planes are often created by copper 'pour' or 'fill' functionality, rather than being specifically drawn. To obtain a microstrip geometry, automatic copper pour needs to be prevented from adding copper close to the trace on the top of the board.

The microstrip geometry is characterised by the thickness of the copper used for the signal trace (*T*); the width of the signal trace (*W*); and the thickness of the circuit board material, which gives the height of the signal trace above the ground plane (*H*).

Stripline

On boards with more than two layers, the signal trace can be run on an internal layer between two ground planes, this is known as a 'stripline', as shown in Fig.3. Like the microstrip, the stripline's geometry characteristics include the signal trace thickness and width (*T*, *W*) and the distance between the ground planes and the signal (*H*). If both ground planes are the same distance from the signal then we have a symmetrical stripline, as in Fig.3, but, of course, asymmetrical striplines with two different *H* values can be created.

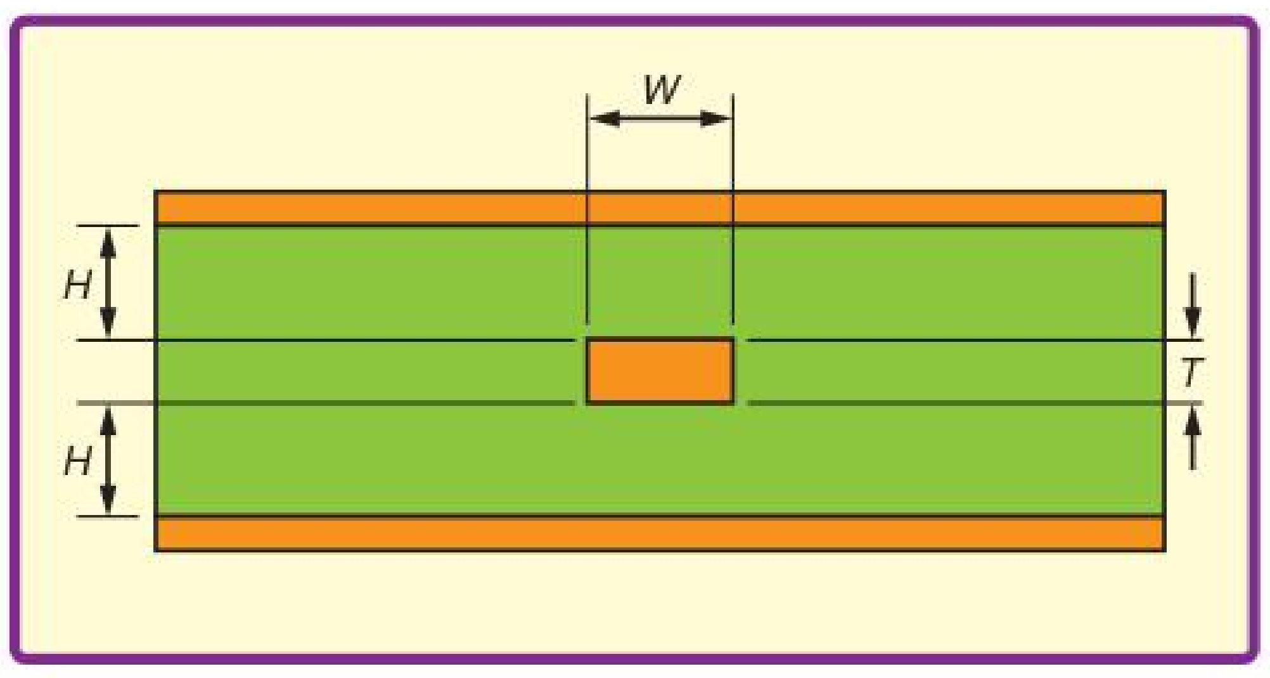


Fig.3. Cross section of a symmetrical stripline PCB trace

Coplanar waveguide

Fig.4 shows another common geometry for double-sided (two-layer) boards, the 'coplanar waveguide' (strictly speaking it is a coplanar waveguide with ground, as just the upper layer on its own is a coplanar waveguide). The coplanar ground plane is separated from the signal trace by a gap of width (*G*). Like the width of the trace, this gap is constant along the length of the trace. The geometry parameters for the coplanar waveguide are the same as for the microstrip, plus the value of *G*, although *T* is less important than for the microstrip and is not included in some calculators.

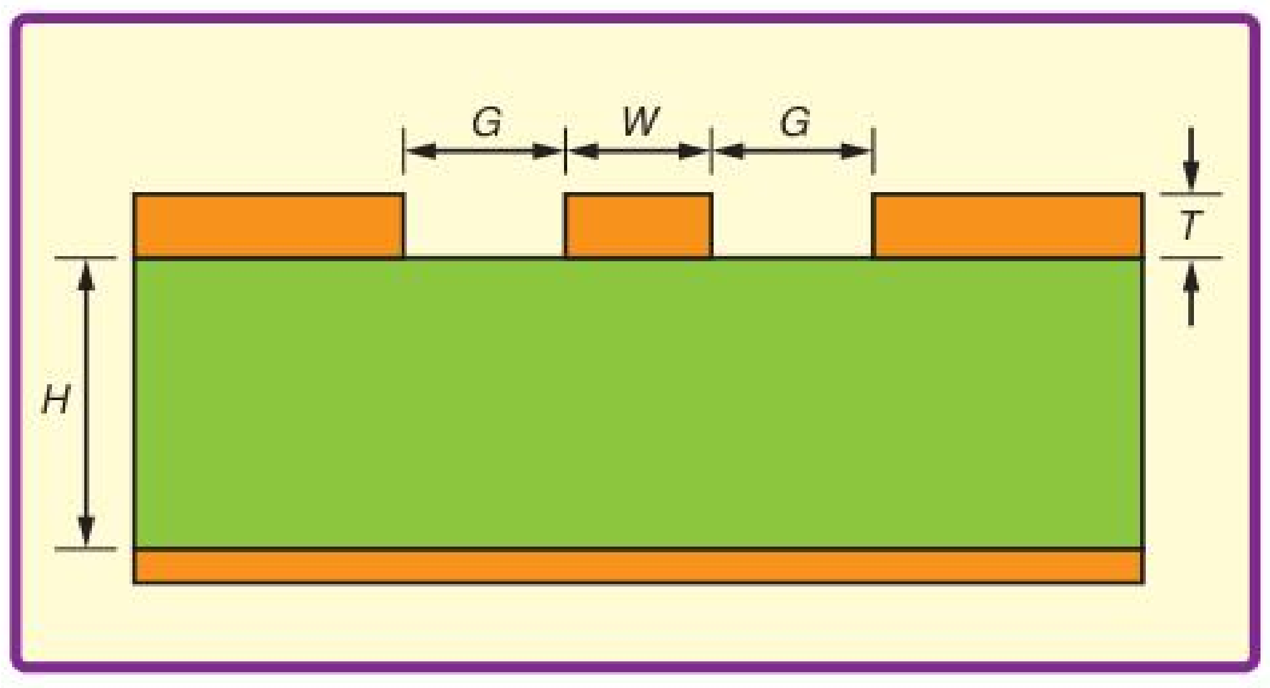


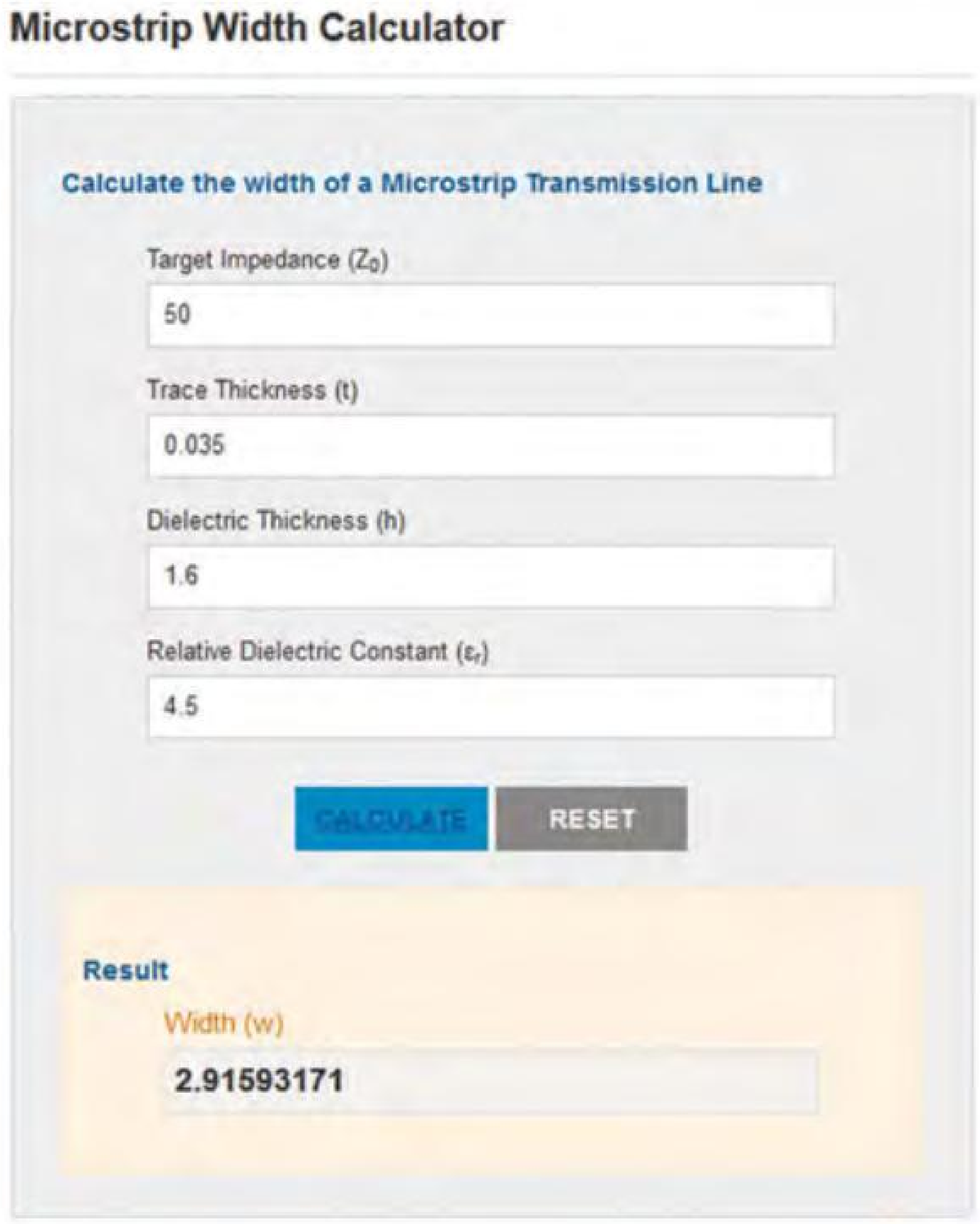
Fig.4. Cross section of a coplanar waveguide PCB trace

PCB design tools

In terms of PCB design tools, the *G* parameter of the coplanar waveguide geometry is often likely to be controlled by the setup of the copper, pour function. When the tool fills unused areas of the board with copper it will stop a certain distance from a trace, which will determine G. One thing to check is that any such copper in areas between signals is actually connected to ground. If not, you have 'floating copper', which may have very unwelcome effects in high-frequency circuits – the line impedance may be wrong and unwanted coupling of signals between different parts of the circuit may occur.

If you know the geometry you want, and have the PCB datasheet values (the dielectric constant and the thicknesses (*T* and *H* parameters in Fig.2 to Fig.4)), then you can use an online calculator to find the right width of trace for the required transmission line characteristic impedance for your circuit design. There are many sites providing line impedance calculators for PCB geometries such as those discussed above, and others. These sites include **everythingrf.com**, **pasternack.com**, **eeweb.com microwaves101.com** and **emtalk.com**

The calculators vary in terms of whether they 'analyse' or 'synthesise'. 'Analyse' means input all the geometry parameters and find out what the


Microstrip Width Calculator

Calculate the width of a Microstrip Transmission Line

Target Impedance (Z_0): 50

Trace Thickness (t): 0.035

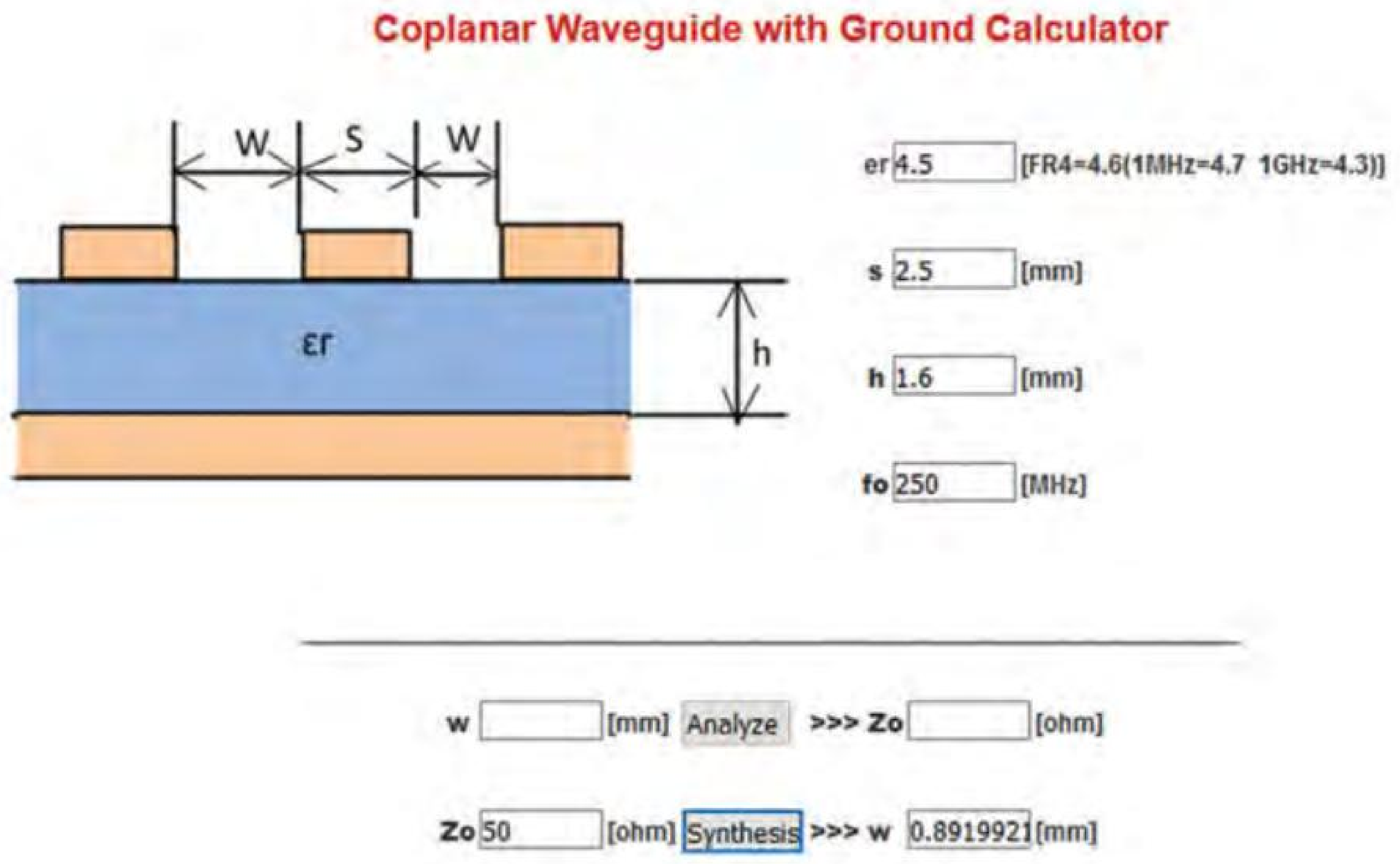
Dielectric Thickness (h): 1.6

Relative Dielectric Constant (ε_r): 4.5

Result

Width (w): 2.91593171

*Fig.5. Screenshot of an example PCB microstrip transmission line design calculator (**everythingrf.com**)*


Coplanar Waveguide with Ground Calculator

er 4.5 [FR4=4.6(1MHz=4.7 1GHz=4.3)]

s 2.5 [mm]

h 1.6 [mm]

fo 250 [MHz]

w [mm] Analyze >>> Zo [ohm]

Zo 50 [ohm] Synthesis >>> w 0.8919921 [mm]

*Fig.6. Screenshot of an example coplanar waveguide with ground PCB transmission line design calculator (**wenshing.com.tw**)*

characteristic impedance is, whereas 'synthesise' means enter the required characteristic impedance and fixed board parameters and find out what trace width (or other dimension) is required.

Fig.5 shows a screenshot of an example microstrip calculation using the calculator from **everythingrf.com** (**http://bit.ly/2rBYdbh**). The calculator shows that for a target impedance of 50Ω on a 1.6mm-thick FR4 board with 1 oz copper (35µm thick), and a dielectric constant of 4.5, the required trace width is about 2.9mm. Note that this calculator, unlike some, does not specify units; this means that all sizes must be given in the same units (eg, mm, mils). Fig.6 shows an example calculator for a coplanar waveguide with ground from Wenshing Electronics Co. Ltd (**http://bit.ly/2smnymy**). This has both analyse and synthesise modes. The screenshot shows synthesis of a 50Ω line for a similar PCB to the previous example. The trace width is input (2.5mm) and the required gap is calculated (0.9mm).

The upper and lower ground planes of a coplanar waveguide (Fig.4) should be shorted together – they will be at some point on the PCB, but circuit performance will be better if they are shorted close to the signal path. This is achieved using what is known as a 'via fence'. A via is a connection between layers on a PCB which is achieved in commercially manufactured PCBs by drilling a hole and plating the sides with metal to form the connection (plated through hole). A via fence is simply a row of closely spaced vias along the edge of the ground plane – a top view of this is shown in Fig.7. The vias are not shown in the cross section in Fig.4. A via fence is a step towards having a solid metal wall between the ground planes, but is much easier to manufacture.

Via fences improve isolation of signals on high-frequency PCBs. To be effective, the vias have to be sufficiently closely spaced, with about 1/20 of the wavelength of the signal being a reasonable rule of thumb.

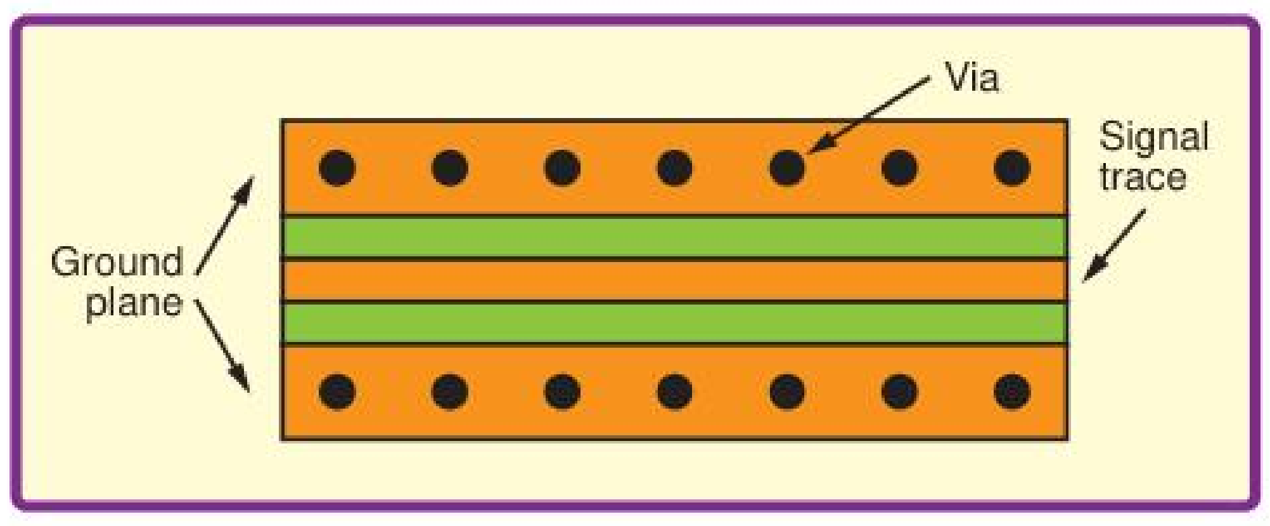


Fig.7. Via fences along the ground plane of a coplanar waveguide signal trace (top view)

Corner design

So far, our discussion has assumed that the signal traces are straight lines; however, practical PCB design often requires traces to change direction. A corner in a fixed-width trace will cause an impedance change and produce signal reflections. One way to avoid this is to use a gradual bend – if the bend radius is more than about three times the width of the trace then reflections should be sufficiently small. Unfortunately gradual bands take up space and cannot be used in all situations. The solution is to use a chamfered corner, as shown in Fig.8 (also referred to as 'mitred'). Using a formula that was published by Douville and James in 1978 in the *IEEE Transactions on Microwave Theory and Technology*, the correct dimensions for the corner can be calculated. The formula is readily available online.

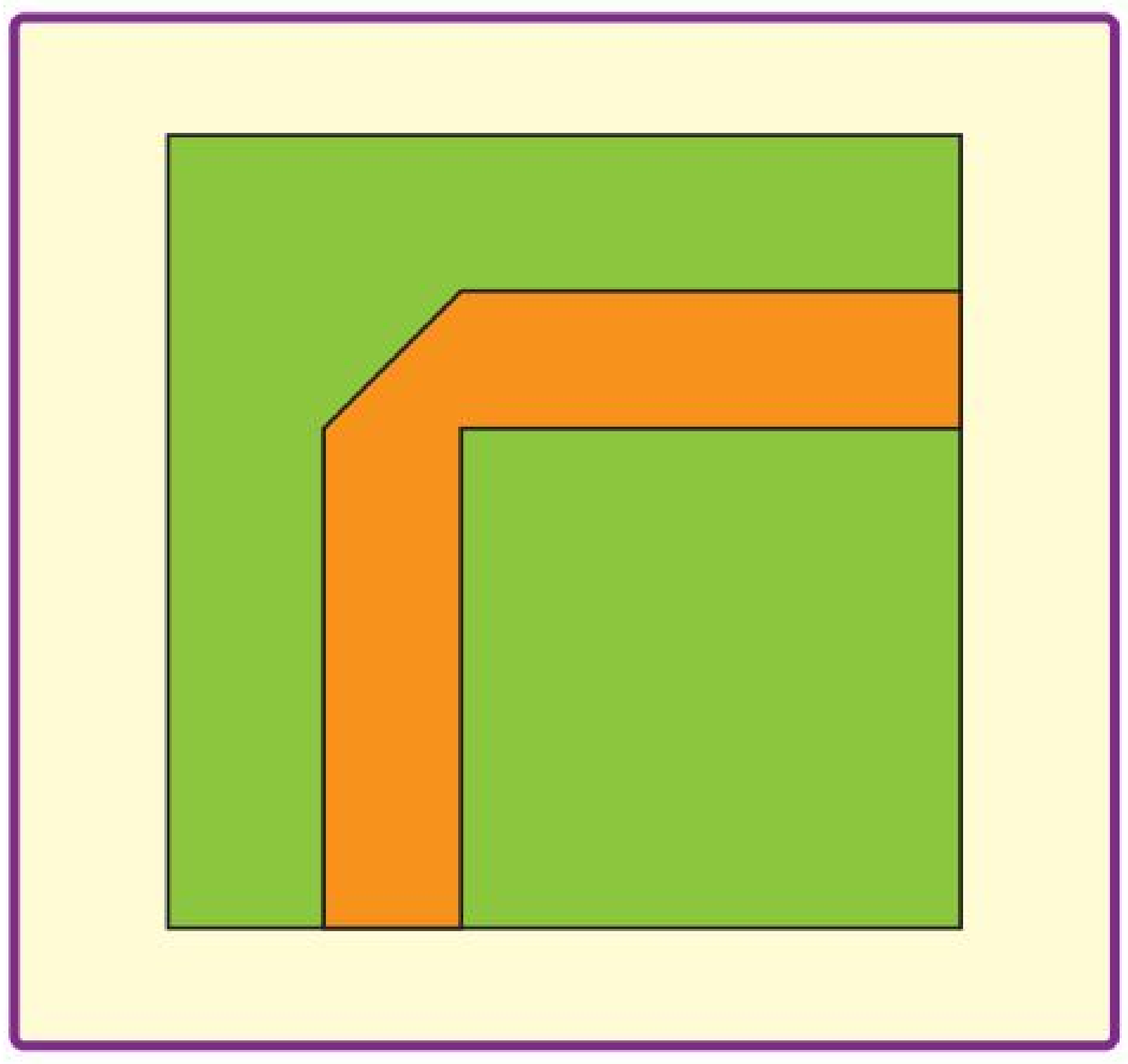


Fig.8. Top view of the layout of a corner geometry that can be used to minimise transmission line reflections.

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AUDIO OUT

By Jake Rothman

Looming problems – Part 1

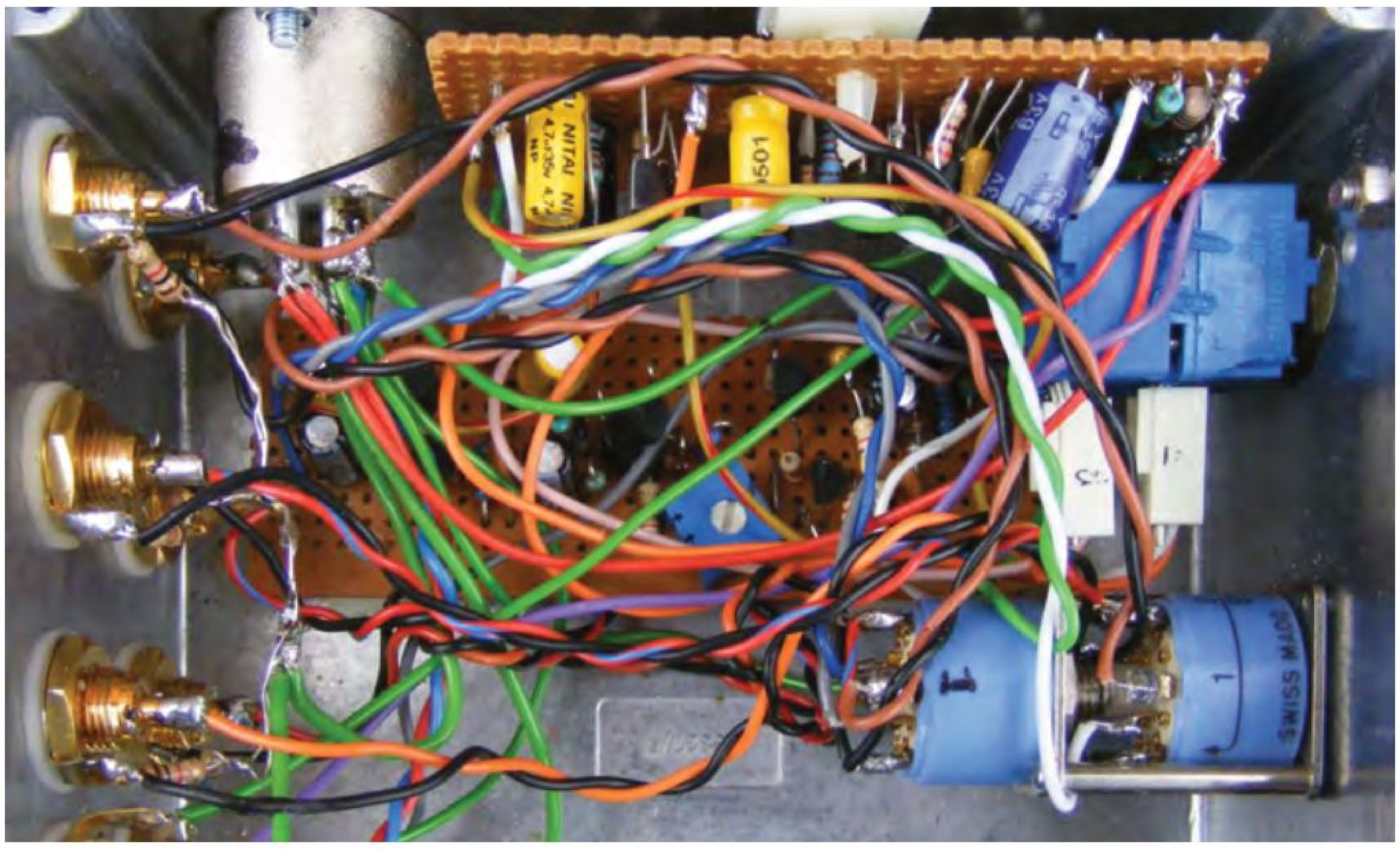

Fig.1. It doesn't have to be like this – use a proper loom.

'Looming problems' – no, we're not talking about the economy, but decent wiring. Most young engineers can solder up a PCB perfectly, but give them a few pots and switches to wire up and a dreadful rat's nest develops (Fig.1) compromising the reliability of the whole system. The solution is to design a proper wiring loom or harness. Maintenance engineer Paul Morrison at the RNLI pointed out this emerging problem to me. The studios, telecoms and railway-signalling sector also report a shortage of wiremen.

Nowadays, it is often considered good design to do away with wires altogether and have everything on the PCB. This allows cheap mass production, but broken joints on components subjected to mechanical forces, such as pots, switches and connectors frequently occur after a few years. You then have the problem of locating a replacement part with not only identical electrical properties, but also the same outline and pins – and sometimes this is just not possible. However, in my experience, quality analogue audio and instrumentation gear can have a useful lifetime of over 30 years if the mechanically stressed parts are hard-wired off board.

Wiring layout

So what are the secrets behind successful wiring? First and foremost, a constructor must work out the wiring layout of the loom. This must include loops for strain relief and future repairs. There's an old adage; 'a wire cut to length will be too short', and there's nothing worse than changing a switch and finding you've got to redo a whole cable run. Always add an extra inch. All the usual electrical rules apply, such as don't loom high-current-carrying cables next to low-level signal wires if possible. A logical pathway for cables between obstacles can usually be developed (Fig.2) and it helps to support the wires if they are kept close to a surface. Adding a couple of spare wires in the loom is also a good idea for future mods, but seal their ends with a little heat shrink. A loop in the loom can be provided for panels and PCBs so they can be hinged back for access.

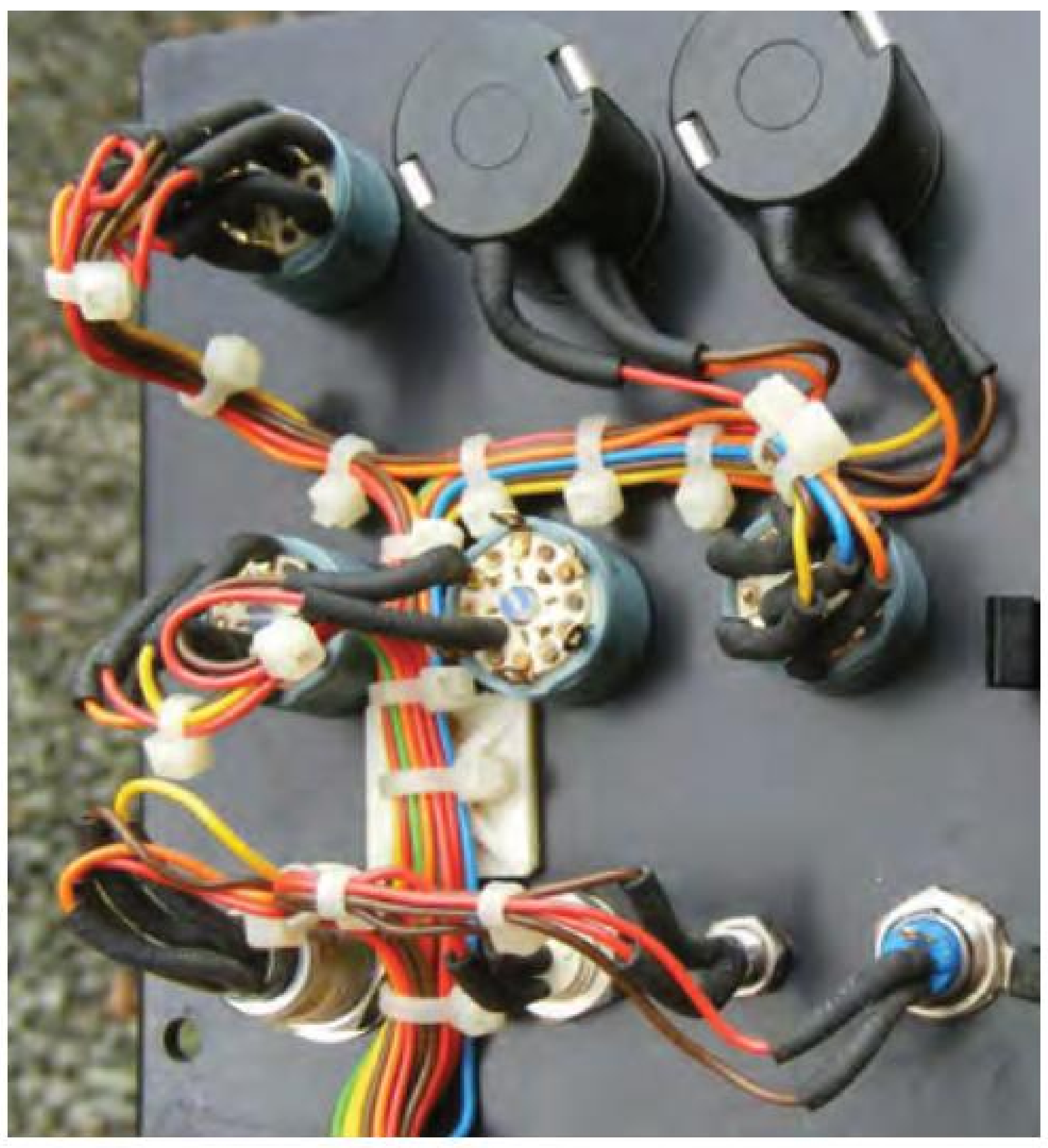

Fig.2. Suitable pathways for the loom around obstacles may take several attempts and can be developed with ties and pads, as in this loudspeaker magnetometer. When finalised, looms can be made up laced, ready for installation.

One important point to remember is that there can be a conflict between good 'mechanical' design and good electrical/electronic design. The circuit electronics may need the shortest-possible cable length for stability, but the mechanical reliability and ease of repair provided by a cable loom will often require a longer cable. I have had to increase the value of phase-lead compensation capacitors across the feedback resistors of op-amps. This is to take into account the increased parasitic capacitance of a cable loom.

Coupling

Coupling between loom wires can also be a problem. Capacitive coupling is mainly a high-frequency problem that can be fixed by using screened cable. Magnetic coupling is a low-frequency problem that can be fixed by tight twisting. This applies to AC, such as the positive and negative power supply wires of power amplifiers and speaker cables. Remember that DC control of front panel functions can obviate coupling problems. The EMS voltage-controlled VCS3 analogue synthesiser has 50 pots and switches with a massive loom.

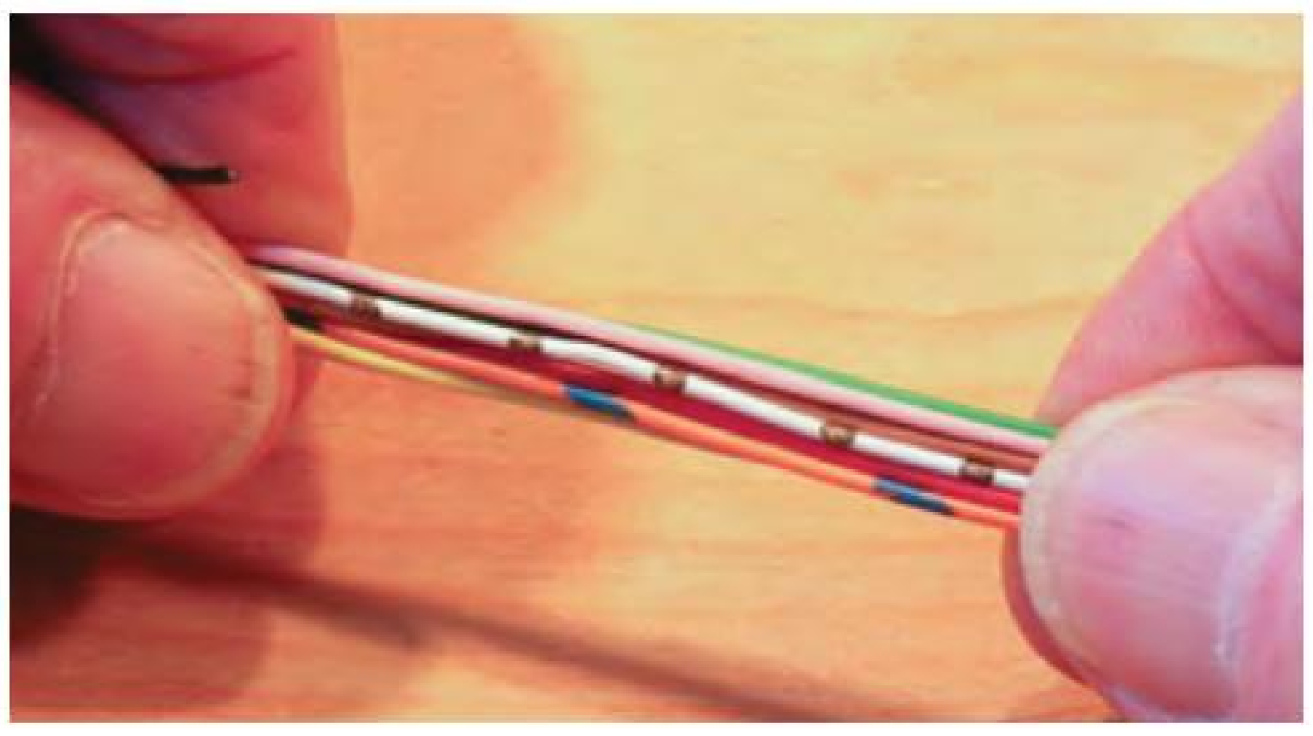

Fig.3. Relieving the tension and straightening out the loom.

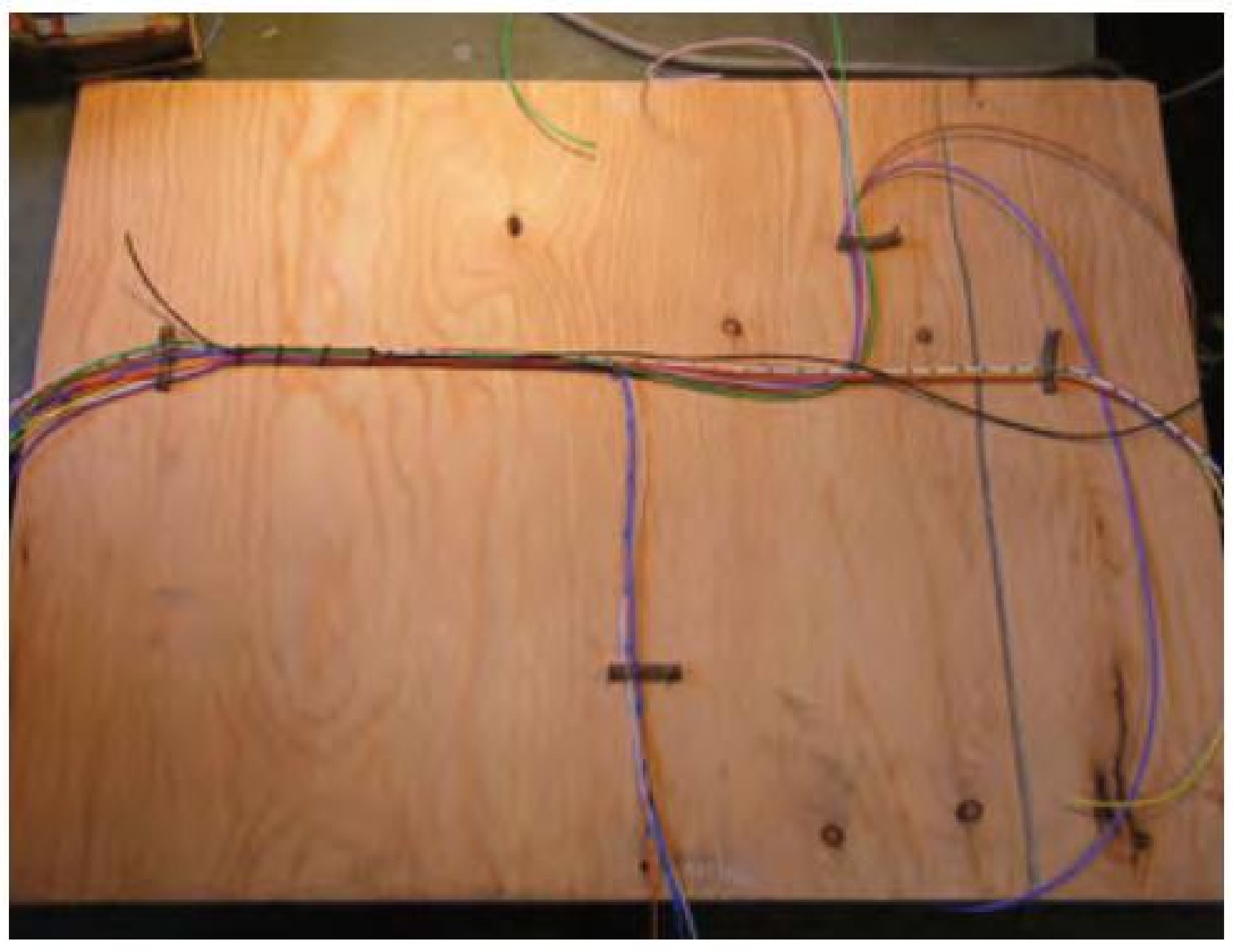

Fig.4. A harness board can be assembled to produce a batch of looms.

Starting

I often start off with a large flat piece of wood for my layouts and I try to get get the 'feel' of a loom and mould it into shape with the thumbs to relieve cable tension and crossovers before tying it up (Fig.3). I usually get the loom for a particular design right after about three attempts. Once I've got it, I may disassemble the loom to get the actual cable lengths needed. I can then make up a batch of looms for a production run on a wooden harness board with nails or springs for anchoring points, as shown in Fig.4. A good tip is to form bends *before* they are tied. Bending after lacing causes problems.

Cables

Don't use solid-core wire; in the real world it snaps after being bent a few times which can even happen during testing. (It is good for inductors, breadboards and house wiring though.) For audio work, stranded wire is preferred. Use 7/0.2 (0.22mm^2) for signal and low-power connections (up to 1.4A) and 16/0.2 (0.5mm^2) for higher power (up to 3A and mains). (Very thin 10/0.1 wire isn't strong enough for looming.) Just getting the standard resistor colour code range is not enough; another 10 mixed colours (with tracers) are needed.

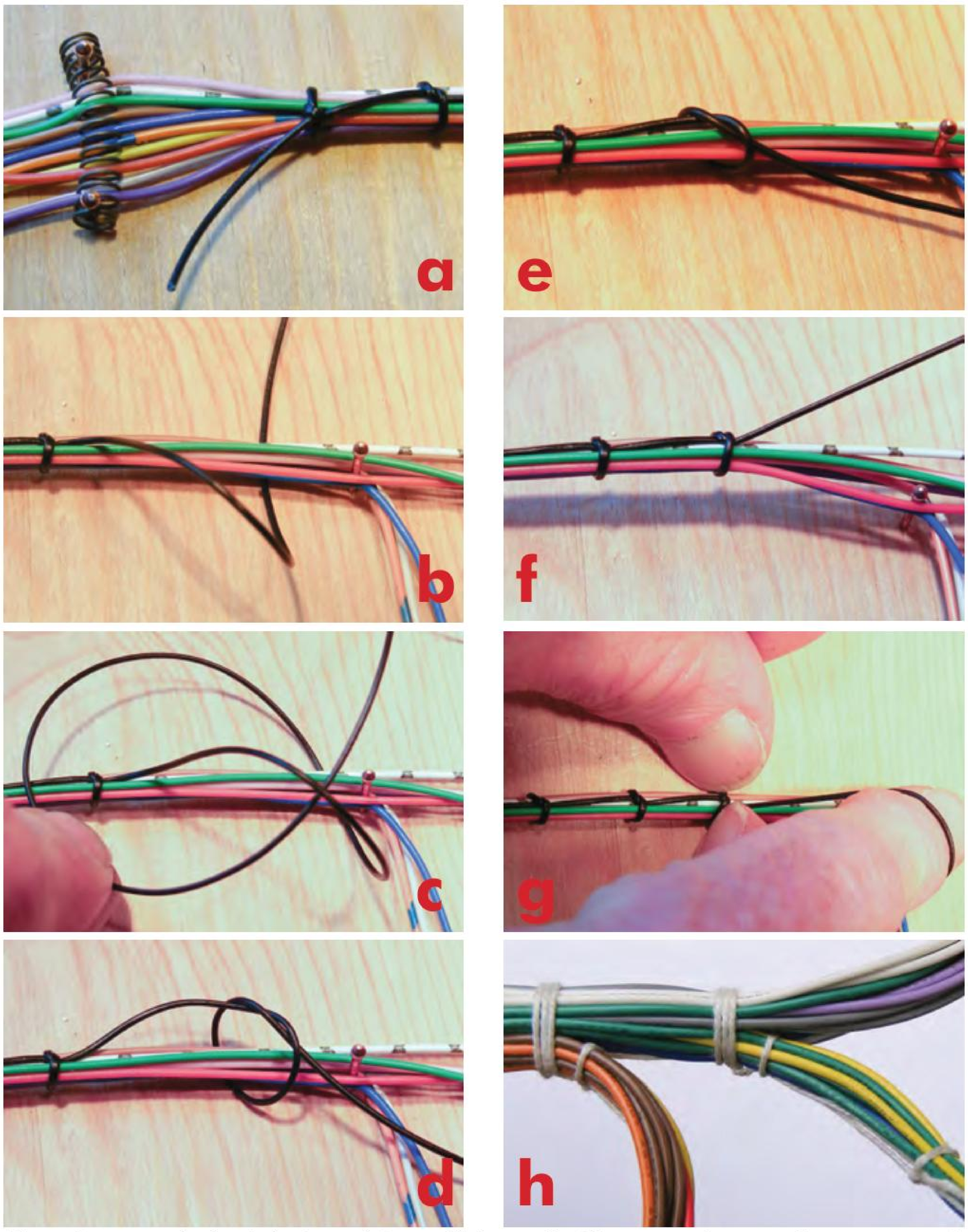

Fig.7. Sequence for basic lacing: a) Start off the cord with a strong knot, such as a surgeon's or square knot; b) Put the cord under the harness; c) Put cord through to form loop; d) The formed twist; e) Tighten the twist; f) Fully tightened twist; g) Straighten things out so it looks good and carry on; h) Branches should be separately tied off.

Cutting ties with ties

Nowadays, everybody laces up a cable loom with cable-ties, which is certainly the fastest way, especially if you use a tie gun (Fig.5). Ties are great for developing the loom and temporary jobs, but the problem is that the hard nylon pinches the cables (Fig.6). The latches protrude and the cut straps edges abrade one's skin. After 10 years or so, the nylon degrades and goes brittle, possibly

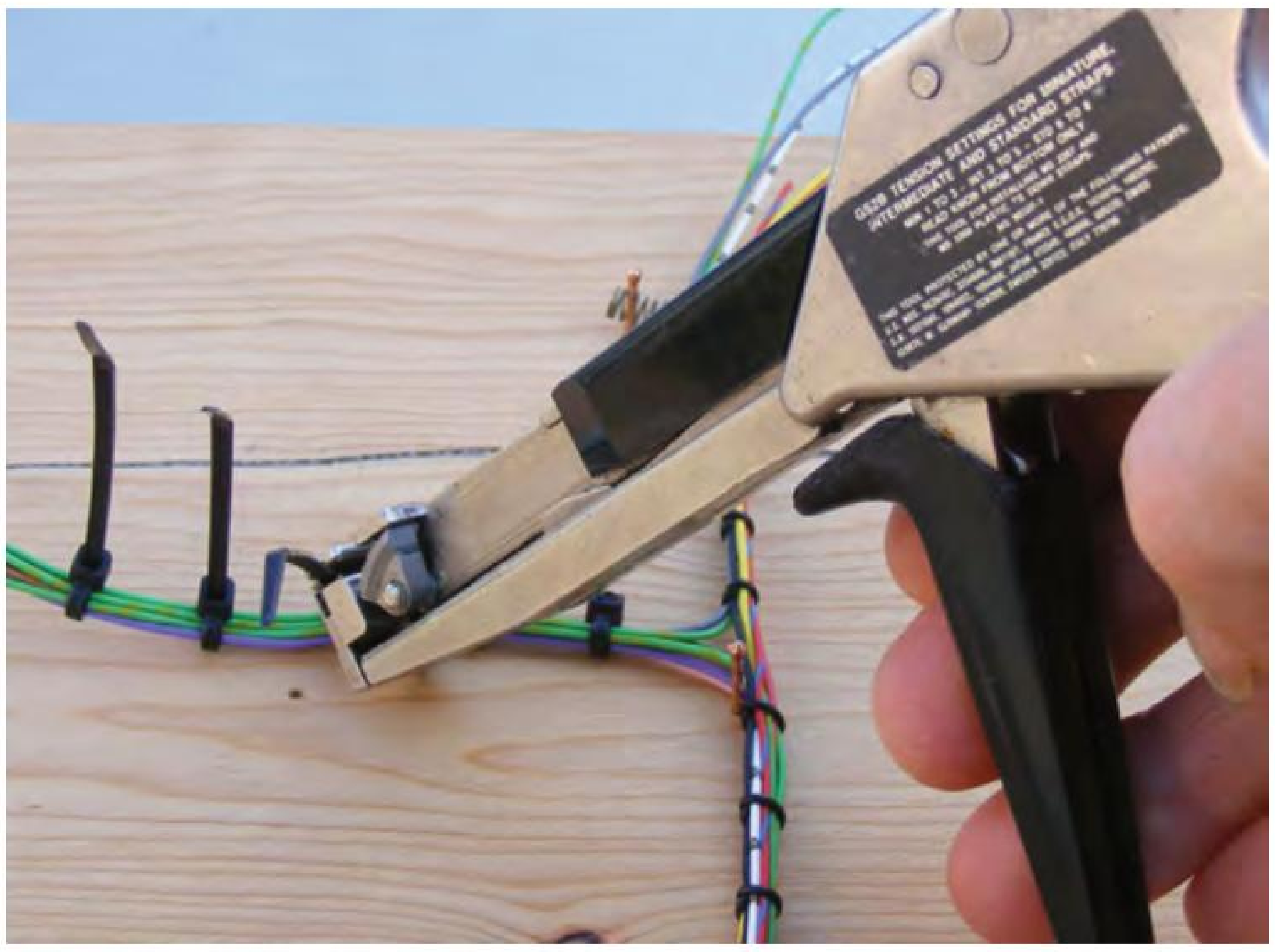

Fig.5 Tie-guns greatly speeds the tightening and cutting process.

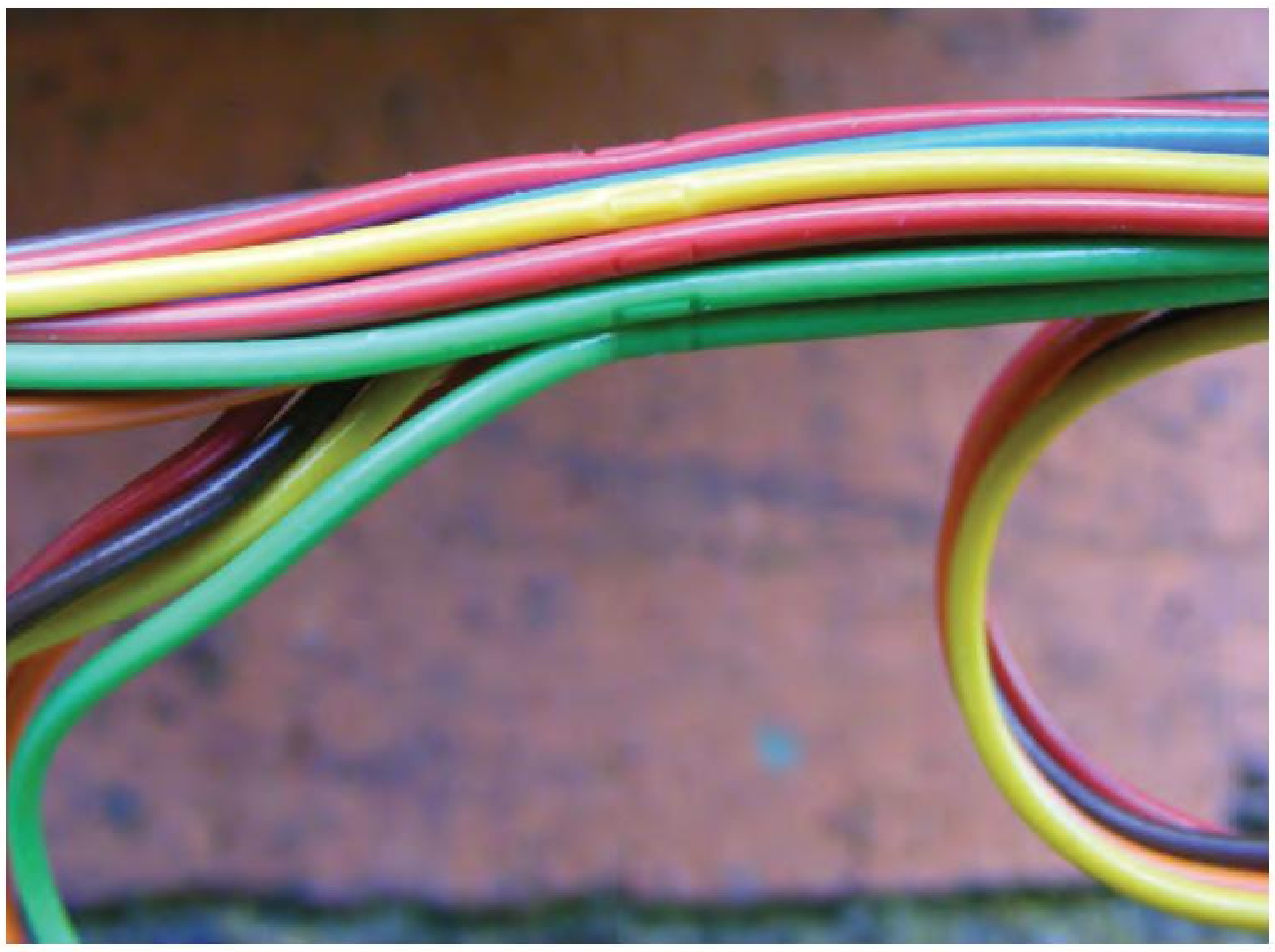

Fig.6. Cable ties can pinch the cable form.

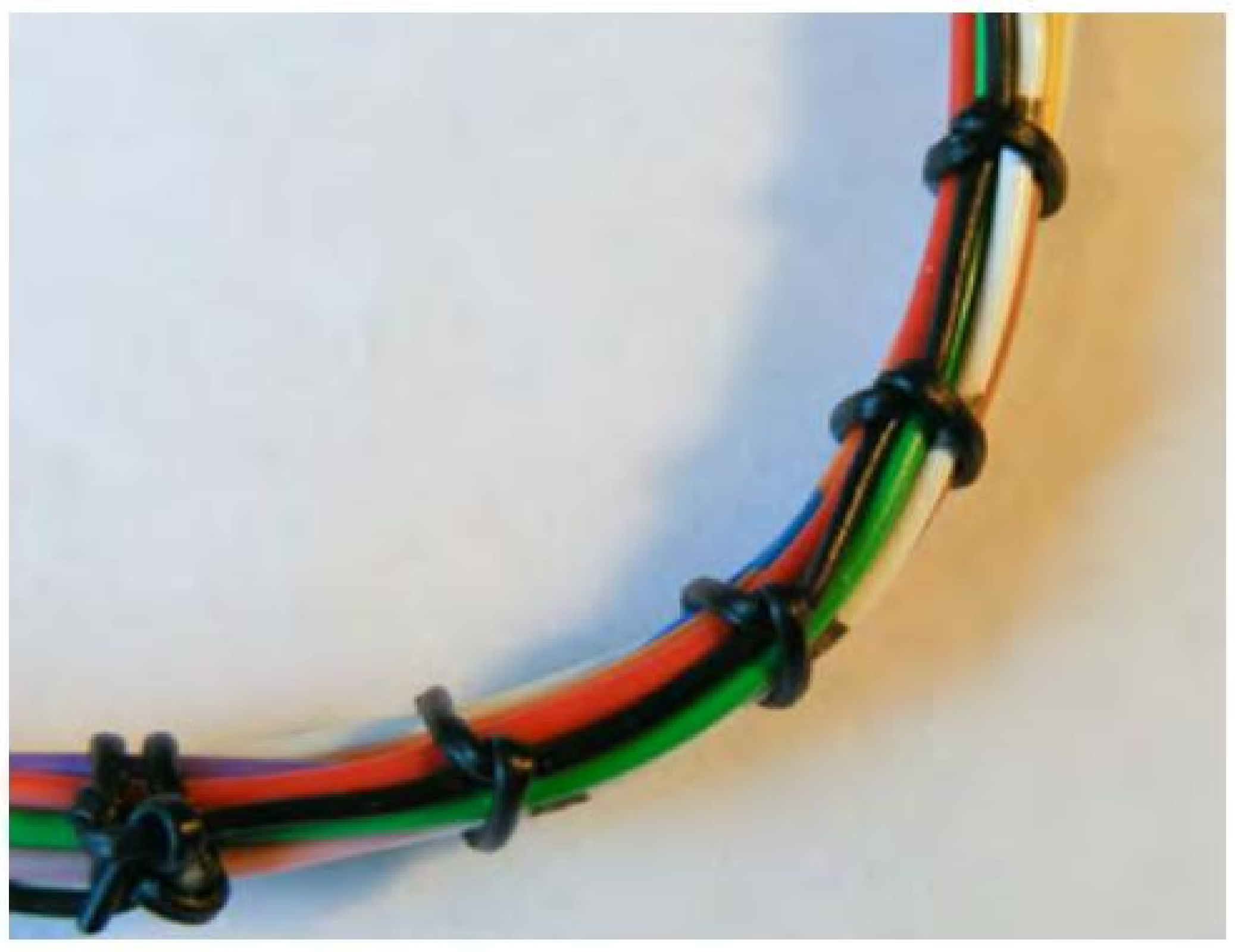

Fig.8. Corners should be laced after forming, with the loops closer together at around 1cm apart.

breaking. There is a better way, and that's *lacing*.

Lacing

Just like properly tying shoelaces this is a forgotten skill; here's a simple way to do it and it's also proven to last. There are stronger, more complex lacing methods for avionics, and they can be easily found on-line. The photos in Fig.7a to 7g show how the basic method is implemented.

The starting and end ties should be a surgeon's knot (http://bit.ly/2s6iy7t) or similar (Fig.7a). (Note the spring holding the wires while you lace). Fig.7b shows the start of the next loop by putting the cord under the harness. Next (Fig.7c) put the cord through the loop to make a twist. Fig.7d shows the formed twist known technically as a 'marlin hitch'. In Fig.7e the twist is tightened, and in Fig.7f the loop is fully tightened. All that remains now is to 'wiggle' the twist into position ensuring the cord is in line with the harness (Fig.7g). If there are branches in the loom, these should be separately tied off (Fig.7h). A sensible loop spacing is 12-18mm, making it closer when going round corners (Fig.8).

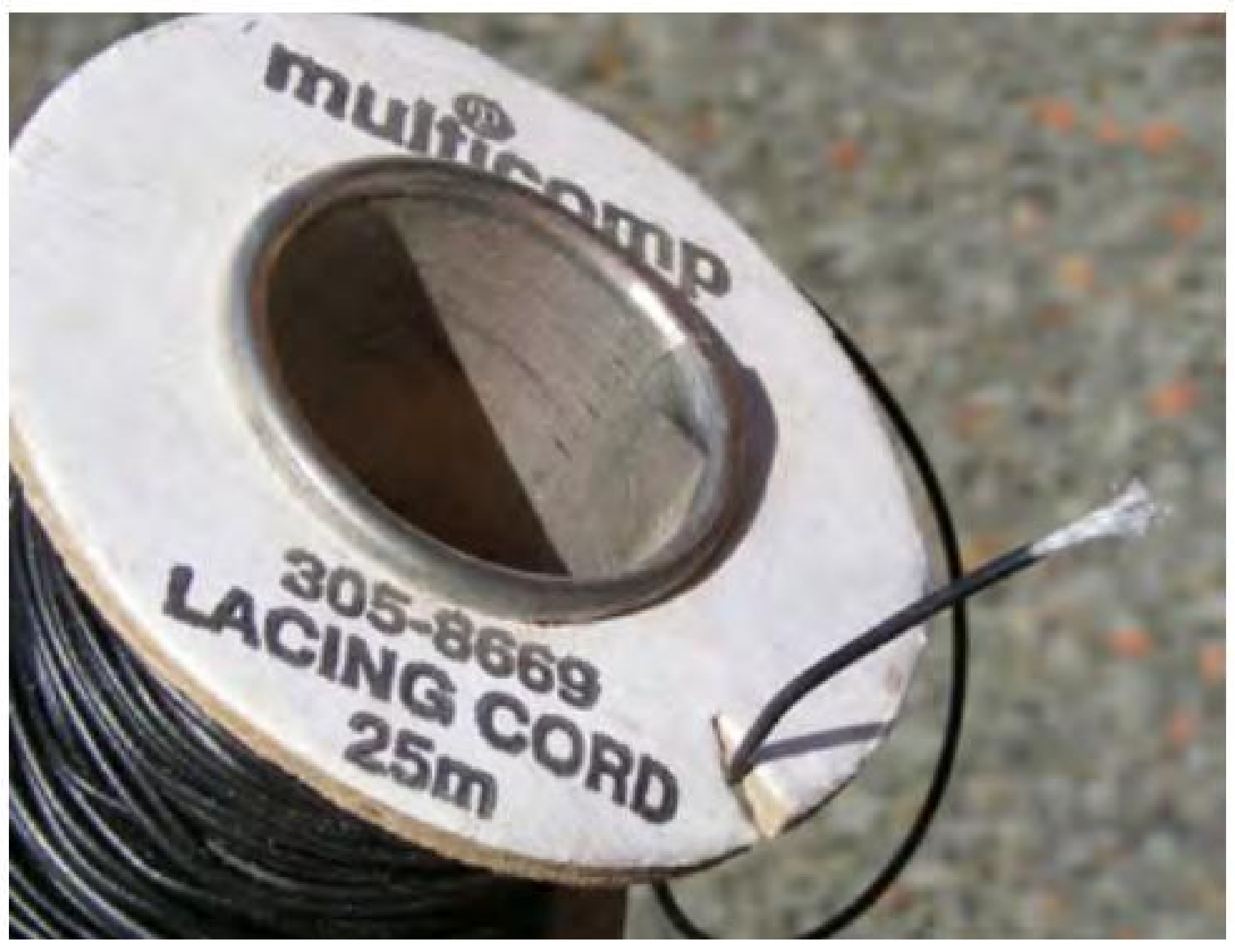

Fig.9. PVC nylon-reinforced cord is strong and looks good, but occasionally unravels.

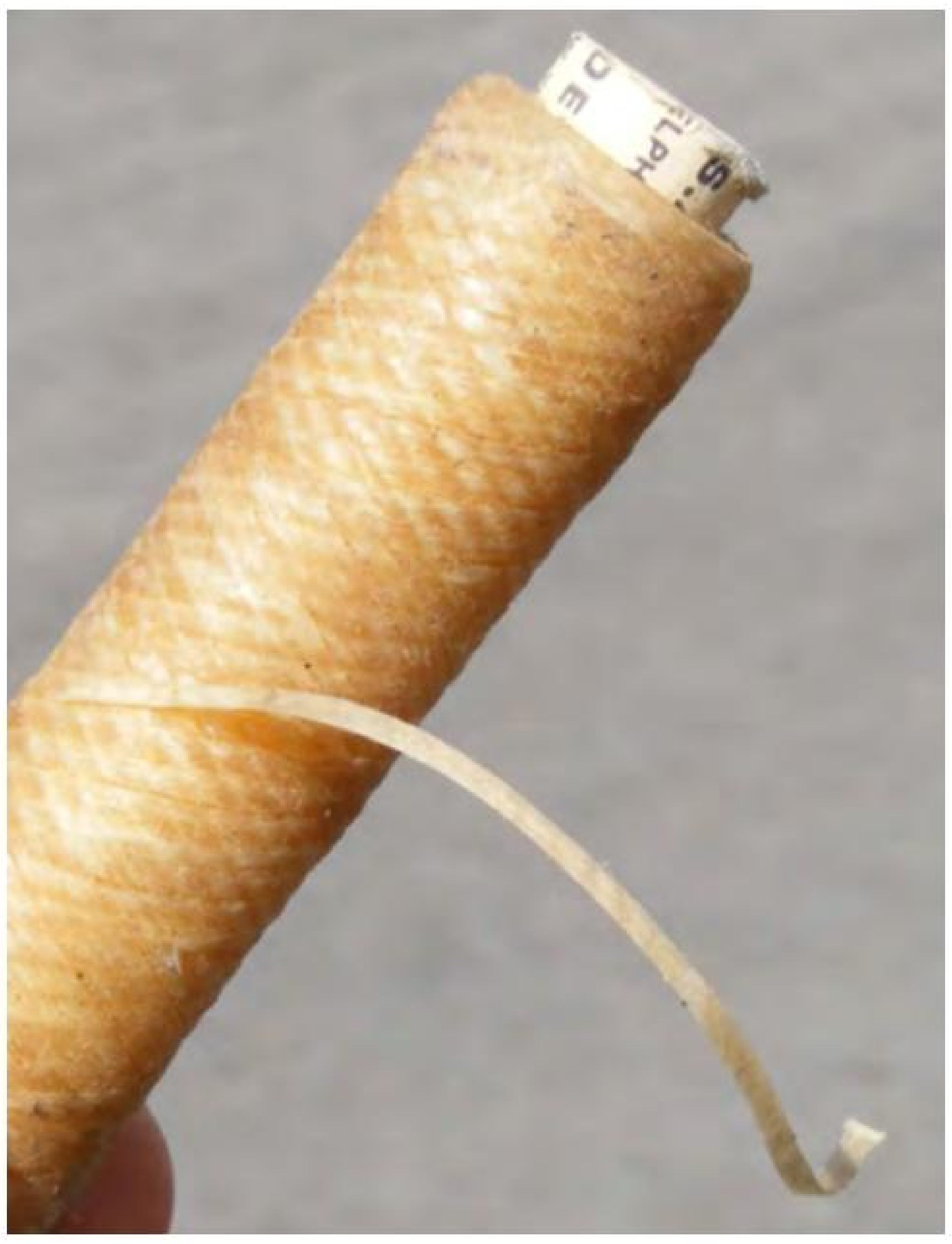

Fig.10. Wax-impregnated cord has superior gripping properties.

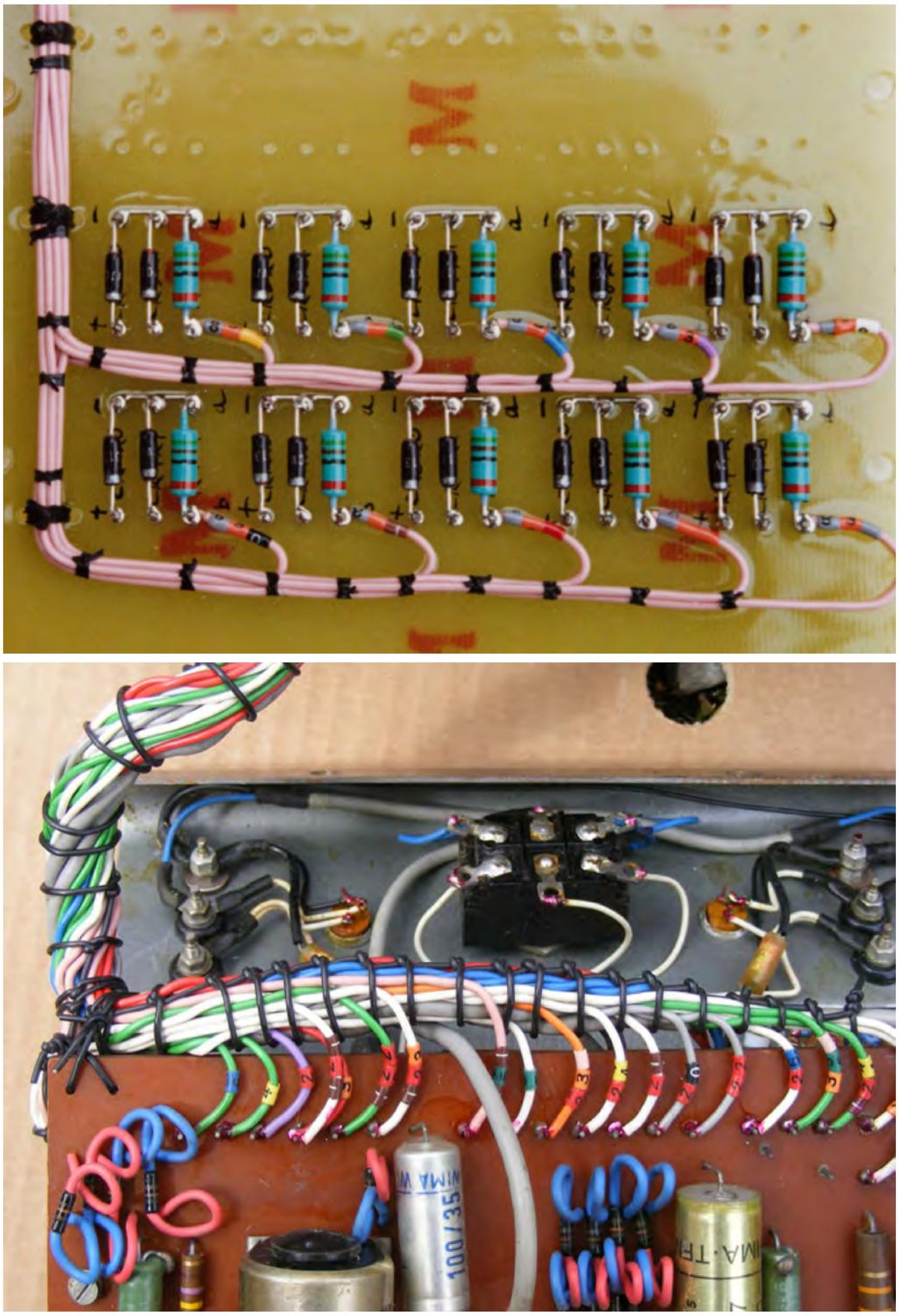

Fig.11. Individual wires can be numbered with push-on sleeves. a) (top) Avionics board, almost a work of art; b) (bottom) Thick harness in an Elliott transistor curve tracer going to multiple pins (Over 50 years old and still intact).

Lacing materials

This all has to be done with lacing materials and there are several types. The most popular is black PVC-coated nylon fibre (Fig.9) which is smooth and strong. It is harder to tie than the wax impregnated type (Fig.10) which provides a high degree of 'stiction', aiding knotting, but it does attract dirt over time. Sometimes 'spot' tying can work, but it's essential to lock the knots with lacquer. This is shown on the avionics board in Fig.11a where the cables are all pink but identified with coloured, numbered slide-on cable markers next to the larger teal resistors. Fig.11b shows a thick PVC/nylon tied loom with markers.

Next month

In September's column I will look at some handy techniques to help you make the most of neat wiring and loom fabrication.

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V_{BE}=1.039V
semiconductor component analyser
automatic lead identification
on - test
scroll - off
warning: avoid charge/voltages

103 x 70 x 20mm

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Just a few example screen shots:

```
PNP Germanium
Transistor        ↓
RED GREEN BLUE
Emit Coll Base    ↓
Current gain
hFE=67            ↓
Test current
IC=2.50mA         ↓
Base-Emitter V
VBE=0.293V        ↓
Test current
IB=4.981mA        ↓
Leakage current
IC=0.027mA        ↓
```

```
NPN Silicon
Transistor        ↓
RED GREEN BLUE
Base Emit Coll    ↓
Current gain
hFE=117           ↓
Test current
IC=2.50mA         ↓
Base-Emitter V
VBE=0.711V        ↓
Test current
IB=4.583mA        ↓
Leakage current
IC=0.000mA        ↓
```

```
PNP Darlington
Transistor        ↓
RED GREEN BLUE
Emit Base Coll    ↓
Diode protection
between C-E       ↓
Current gain
hFE=9124          ↓
Test current
IC=2.50mA         ↓
Base-Emitter V
VBE=1.321V        ↓
Test current
IB=3.720mA        ↓
Leakage current
IC=0.000mA        ↓
```

```
Enhancement mode
N-Ch MOSFET       ↓
RED GREEN BLUE
Gate Drn  Srce    ↓
Gate Threshold
VGS=3.47V         ↓
Test current
ID=2.50mA         ↓

Diode or diode
junction(s)       ↓
RED GREEN BLUE
Anod Cath         ↓
Forward voltage
VF=0.694V         ↓
Test current
IF=4.663mA        ↓
```

```
Three terminal
bicolour LED      ↓
Pinout for D1
                  ↓
RED GREEN BLUE
     Anod Cath    ↓
Forward voltage
D1 VF=1.983V      ↓
Test current
D1 IF=3.223mA     ↓
Pinout for D2
                  ↓
RED GREEN BLUE
Anod      Cath    ↓
Forward voltage
D2 VF=1.927V      ↓
Test current
D2 IF=3.281V      ↓
```

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Max's Cool Beans

By Max The Magnificent

Deep in the mists of time

Back in the 1990s (when I was young Max) computer memory was physically large and tremendously expensive, so we didn't have a lot of it to play with. As one example, I used to write programs to test PCBs using a GenRad 2225 tester. This was about the size of a small carry-on suitcase with a connector into which you plugged the circuit board. Consider the simple PCB in Fig 1. The copper 'fingers' on the bottom of the board were pushed into the tester's connector. Of course, there could be hundreds of inputs and outputs, but we're keeping things simple. The first task was to code in a text-based netlist to inform the tester that input in1 was connected to wire w1; that wire w1 was also connected to pin 2 of IC1 and that this pin was an input; that pin 6 of IC1 was an output and that it was connected to wire w2; that wire w2 was also connected to pin 2 of IC2 and that this pin was an input… and so on.

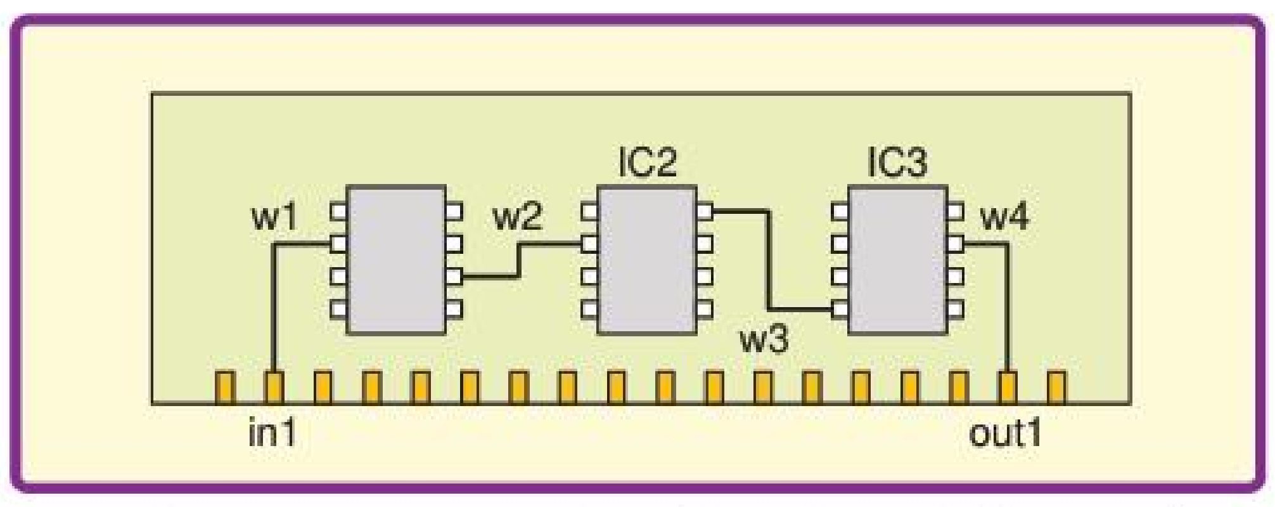

Fig.1. A very simple circuit board

The test program set up a pattern of 0s and 1s on all the inputs and then clocked this pattern into the board. Next, the program read the values from all the outputs and compared them to the values you told the tester you expected. Of course, if there were registers or memory elements on the board (and there usually were), then it might take several clock cycles before the effects of one set of inputs propagated themselves through the board to the outputs.

If one or more outputs didn't carry the expected values, then the user was prompted to use a 'guided probe' – that is, a wire with a probe on one end (the other end was connected to a special input on the tester). The program would guide the user to probe the outputs and inputs of different ICs until a broken chip or wire was found.

I don't want to go into too much detail here, but a program could easily boast 10,000 test vectors. Also, the board could easily have 1,000 nodes (pins/wires). Since you had to capture and store the state of each node for each clock cycle, this meant that you potentially needed enough memory to store 10,000 × 1,000 = 10,000,000 bits of data – a huge slab of memory back then.

The GR-2225's solution was to generate a cyclic redundancy check (CRC) value for each node. This was based on the concept of a linear feedback shift register (LFSR) – a 3-bit LFSR is shown in Fig.2.

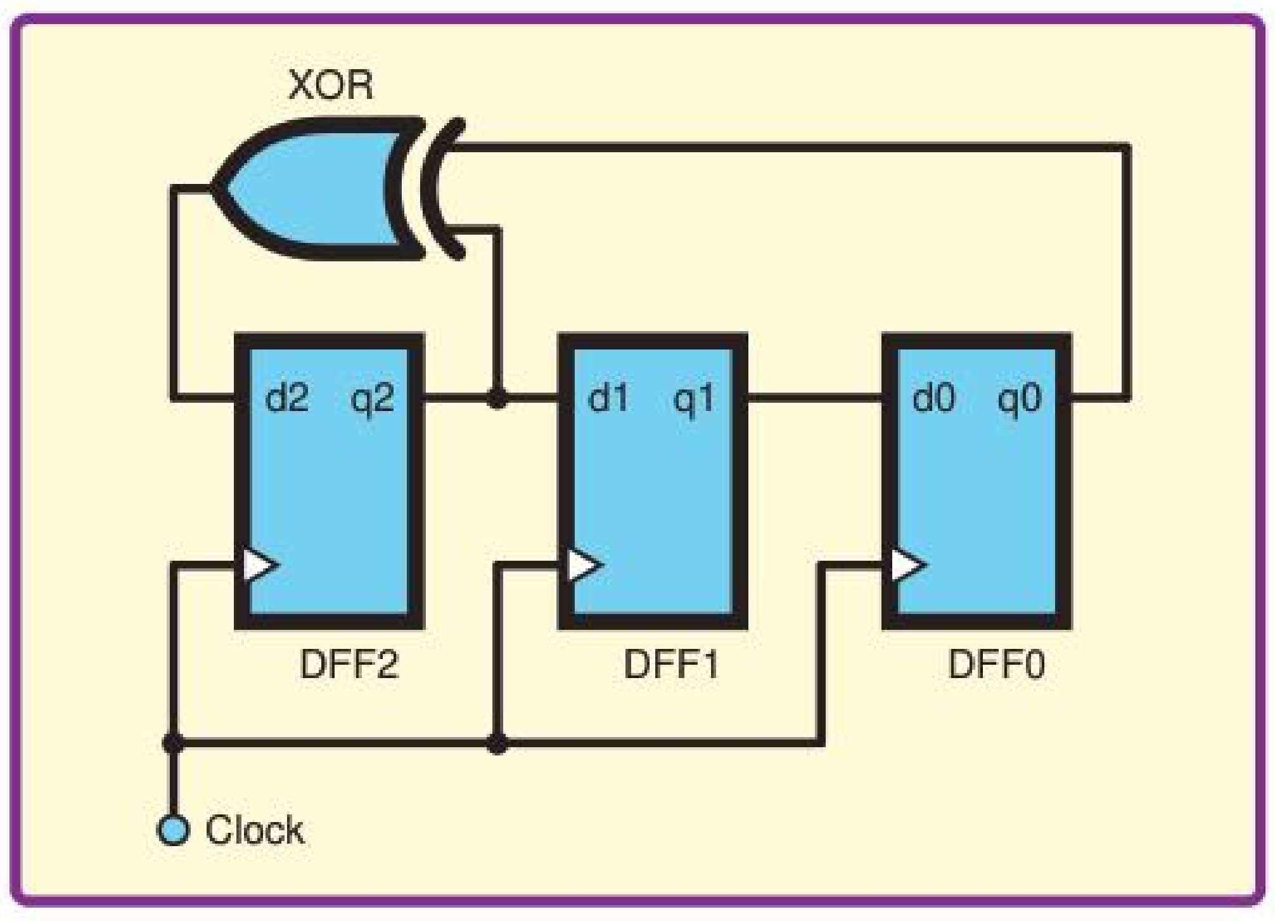

Fig.2. 3-bit LFSR

The feedback points (the outputs from flip-flops DFF2 and DFF0, in this example) are called 'tap points' or 'taps'. These are XORed together, and the output from the XOR function is used to drive the input to the first flip-flip in the chain (DFF2 in this example). Let's assume that we load the flip-flops with a seed value of 001 (that is, DFF2 contains 0, DFF1 contains 0, and DFF0 contains 1). Repeatedly clocking the LFSR will cause it to pseudo-randomly cycle through all the possible patterns except 000 – in this case, 100, 110, 111, 011, 101, 010 – before returning to its initial value.

Now consider what happens if we connect an additional, external input into the LFSR, as illustrated in Fig.3. The idea is that 0s and 1s on the data input are used to modify the contents (sequence) of the LFSR. The result is a CRC generator that can be used for a wide variety of tasks.

For example, we could create an application that took the contents of a file on our system and used these contents to generate a unique CRC value that would be stored somewhere. Later, we could use this CRC value to check that the file hadn't been modified in any way (this is one technique used by anti-virus software).

Another example is to take a block of data that we wish to transmit from one system to another. While the data stream is being transmitted, the transmitter can also be generating a corresponding CRC value. Meanwhile, the receiver will generate its own CRC value while it's receiving the data. At the end of the transmission, the transmitter will send its CRC, and the receiver will compare this to the one it generated. If the two CRCs are different, the receiver can signal the transmitter requesting a data re-send.

In the case of our PCB tester, the CRC generator was used to generate and store a unique CRC (we called them 'signatures') for every signal on the board. Of course, a 3-bit CRC isn't much use, because it can only contain 2^3 = 8 different patterns of 0s and 1s. This means that, although a single bit error on the data stream would cause the CRC sequence to diverge, a second or third error could easily cause it to return to the original sequence.

Thus, we used 16-bit (2-byte) words in which to store our CRCs, because 2^{16} = 65,536 different patterns of 0s and 1s, which makes it extremely unlikely that multiple errors would return the CRC to its original value. Do you remember earlier when we said our board could easily have 1,000 nodes? Well, using our 16-bit CRCs, we would require only 2,000 bytes to store our signatures, irrespective of the number of test patterns we use.

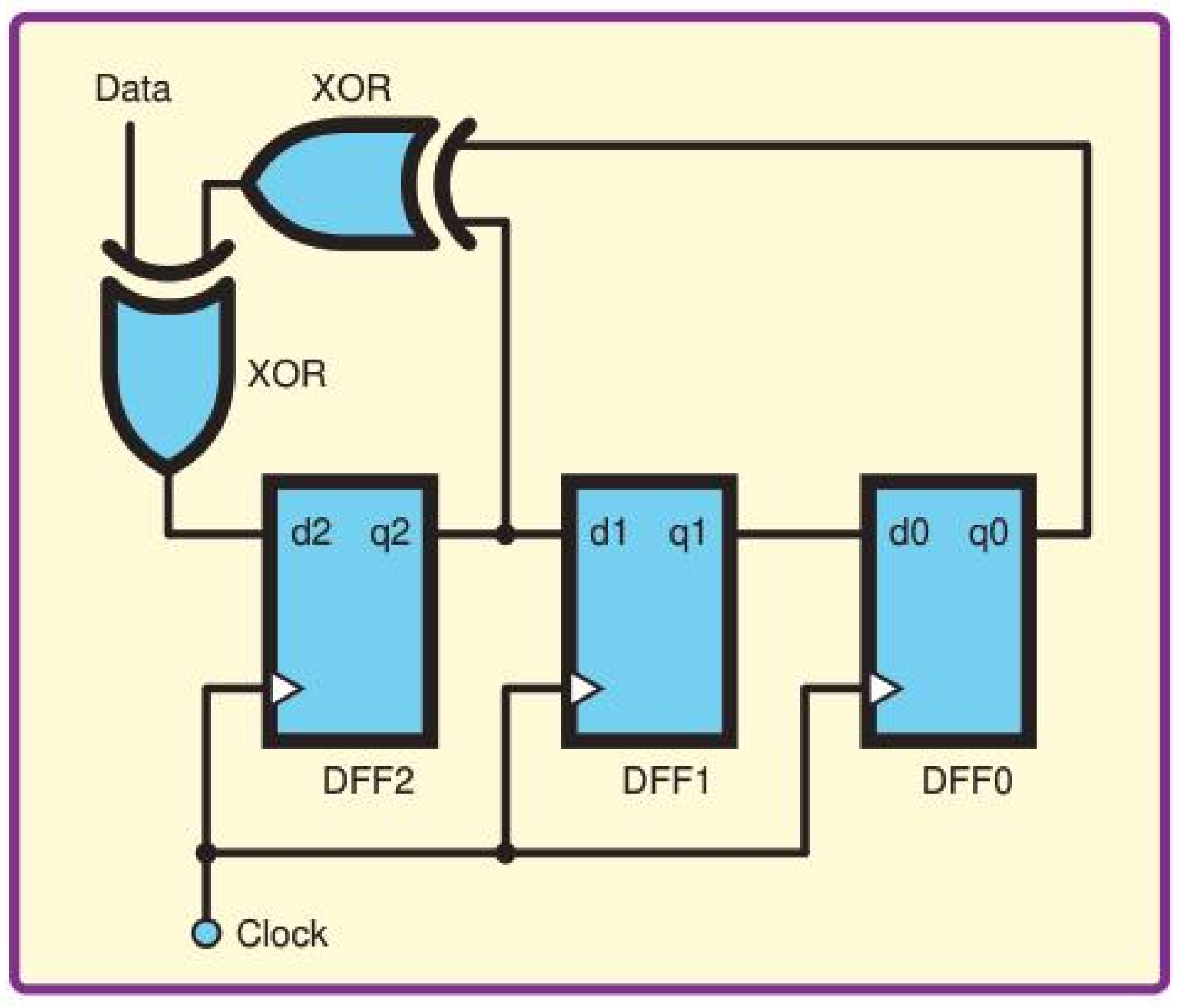

Fig.3. 3-bit LFSR-based CRC generator

Pretty clever, eh? There are lots of other cunning tricks we used to employ, as we'll see in my next column. Until then, have a good one!

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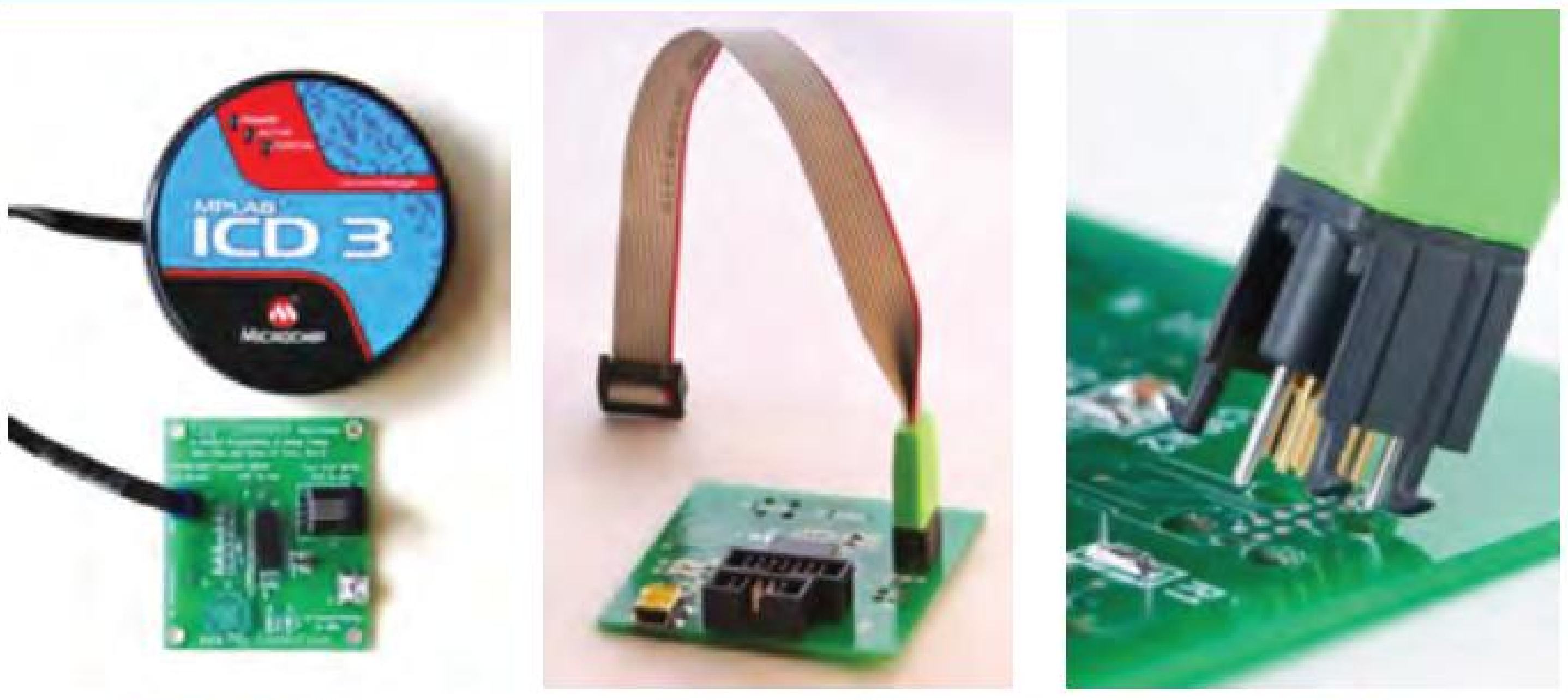

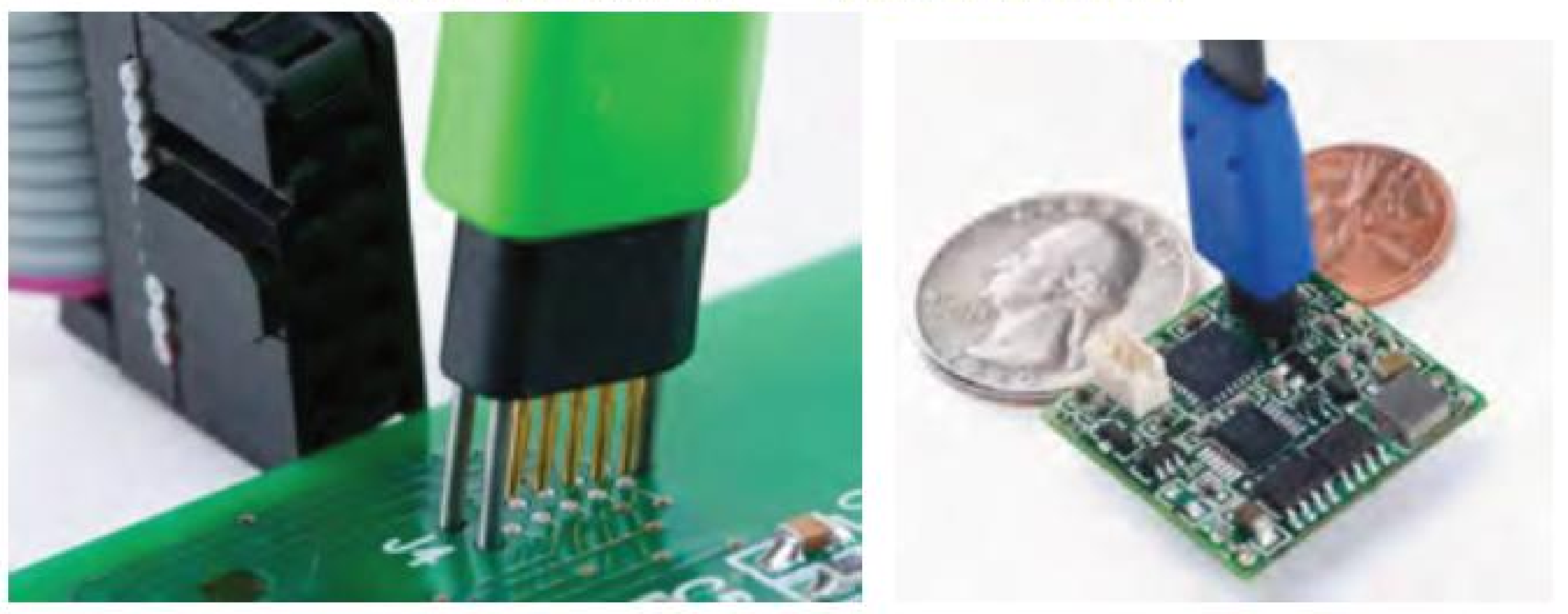

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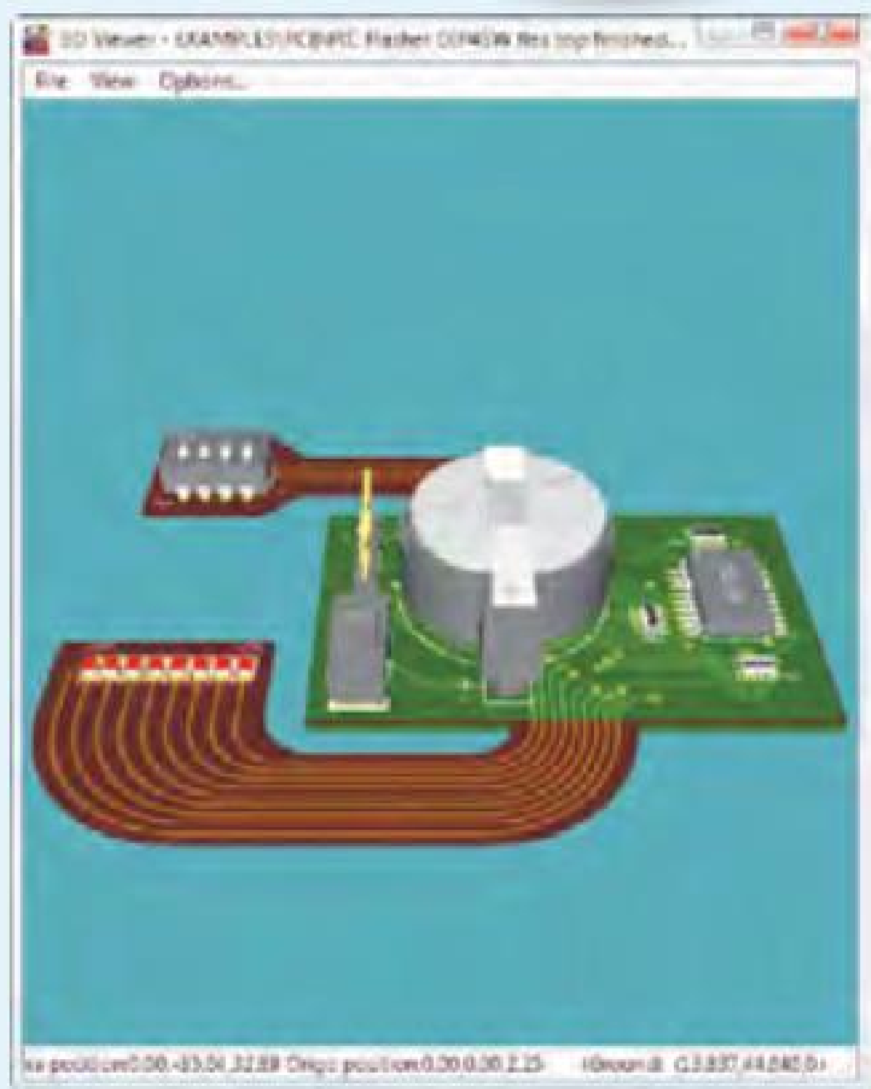

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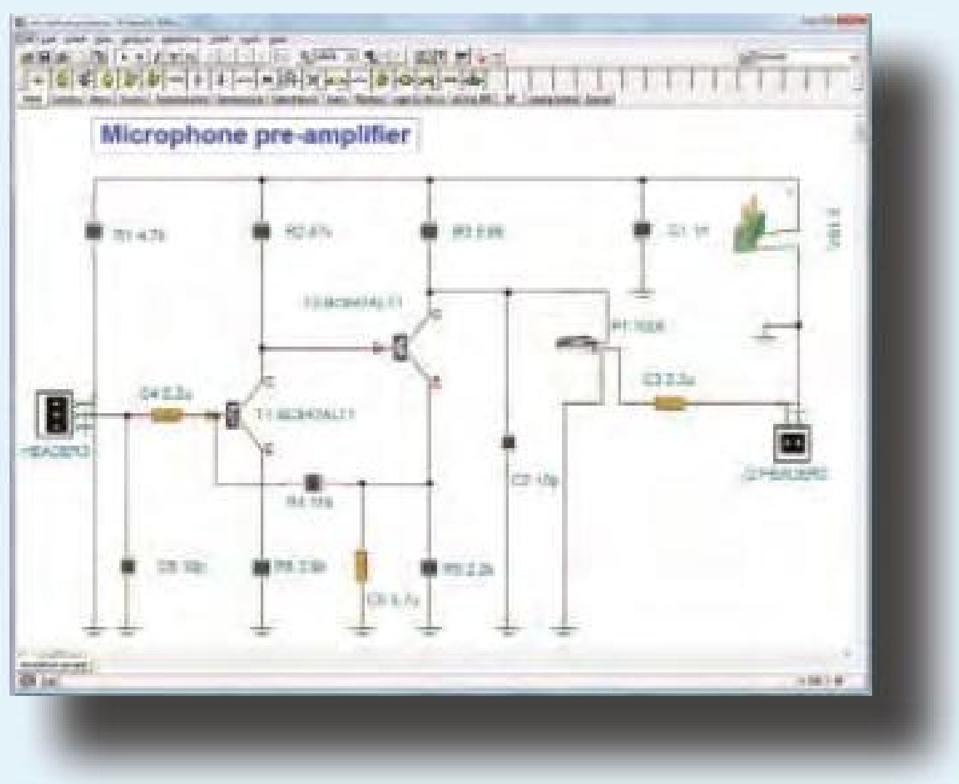
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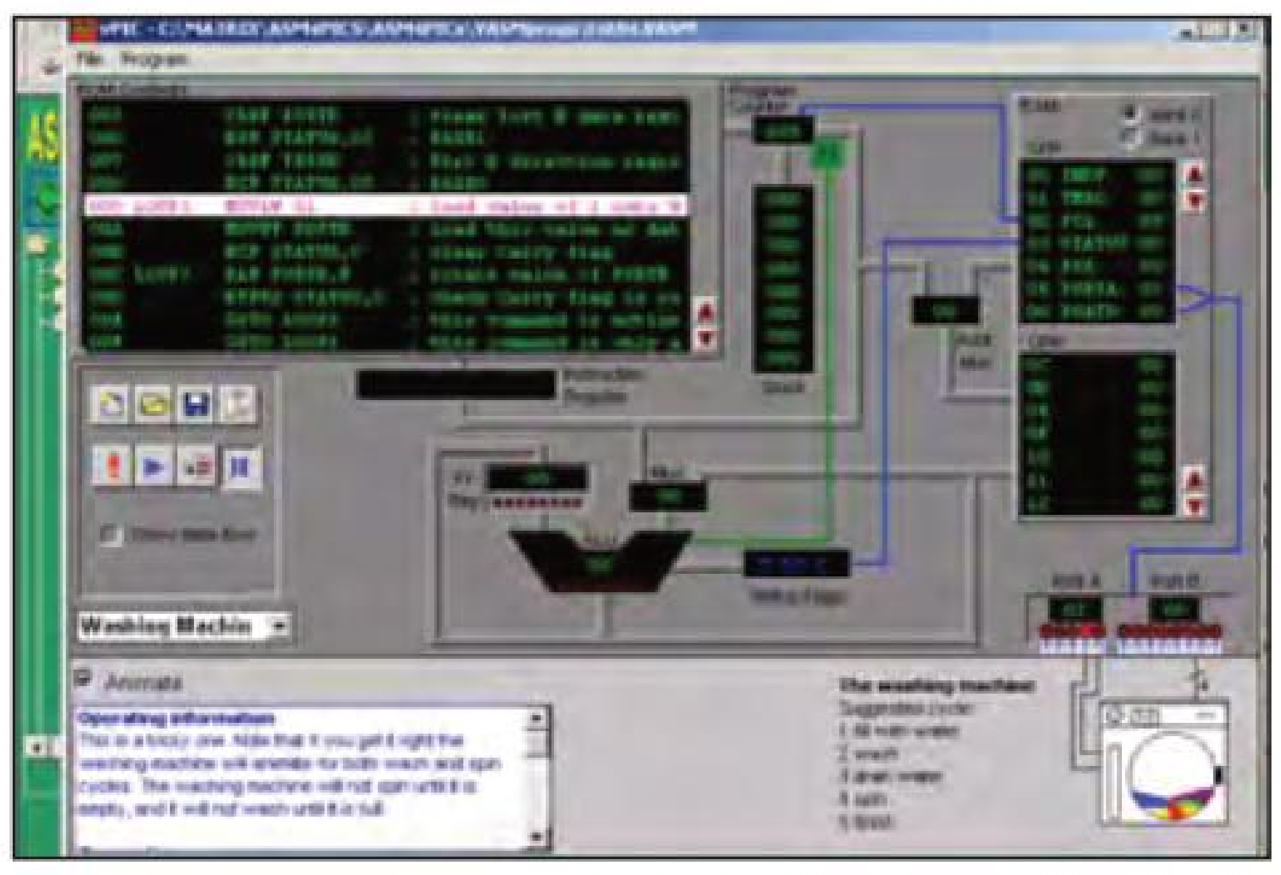

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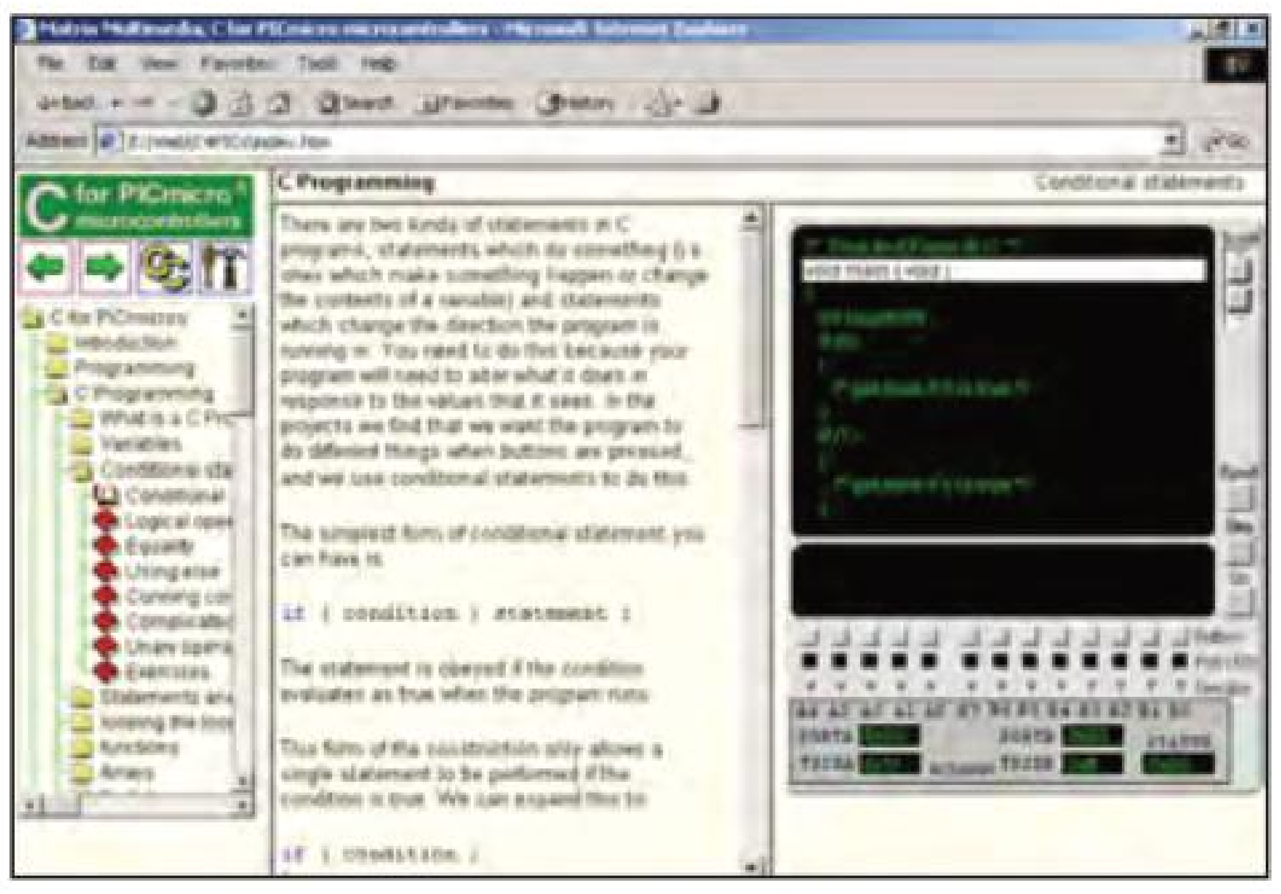

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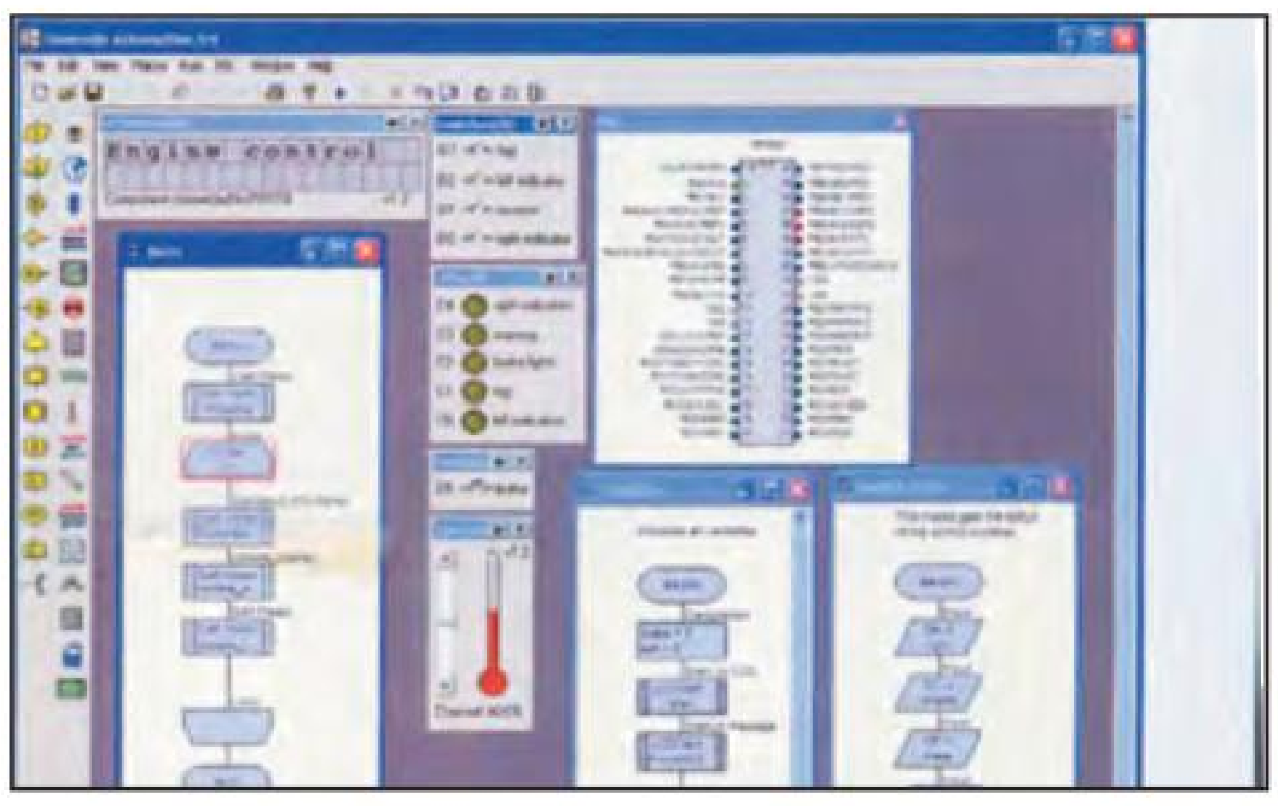

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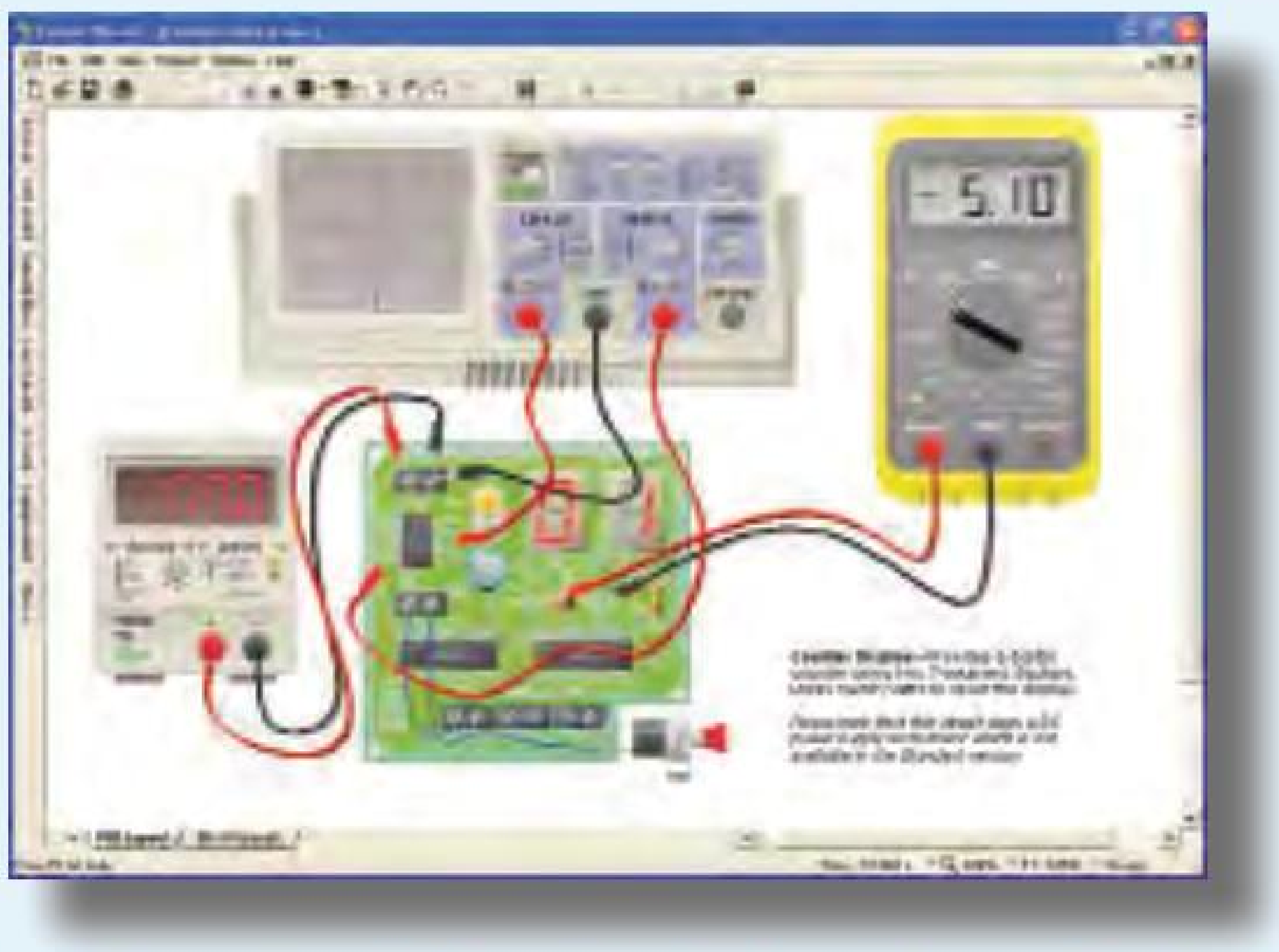

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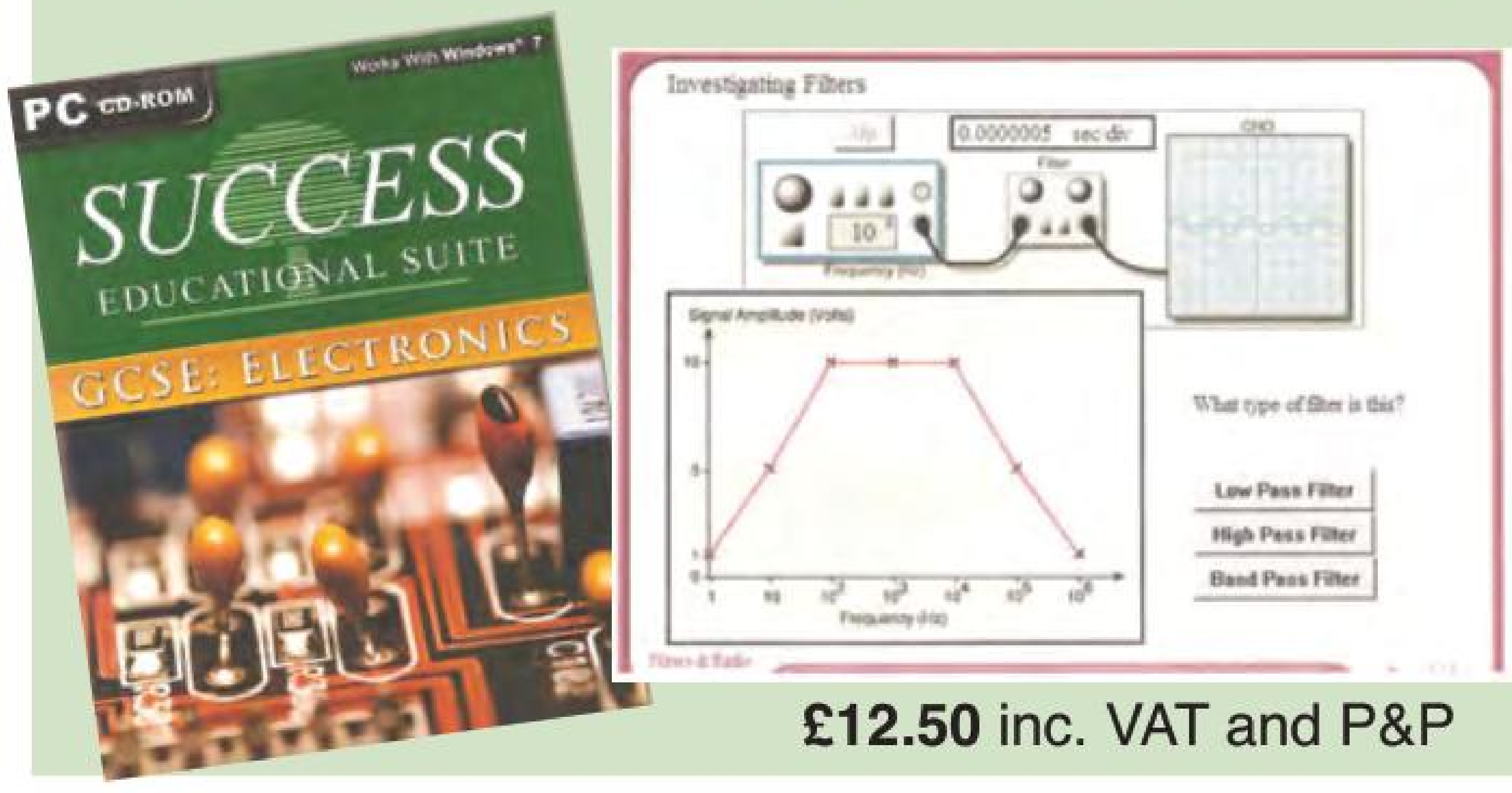

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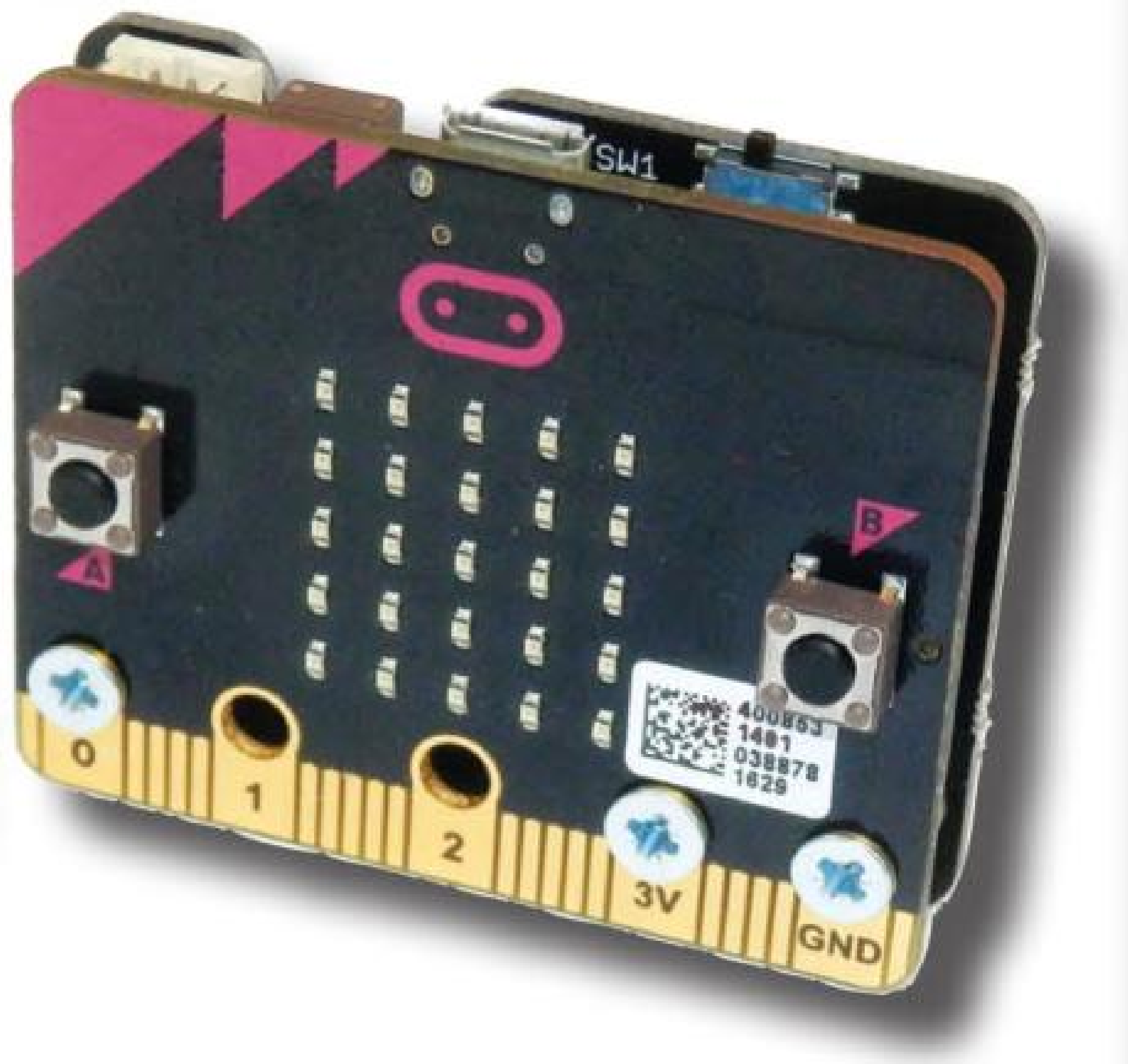

GETTING STARTED WITH THE BBC MICRO:BIT
Mike Tooley

For Beginners of Any Age
Getting Started with the BBC micro:bit
Mike Tooley

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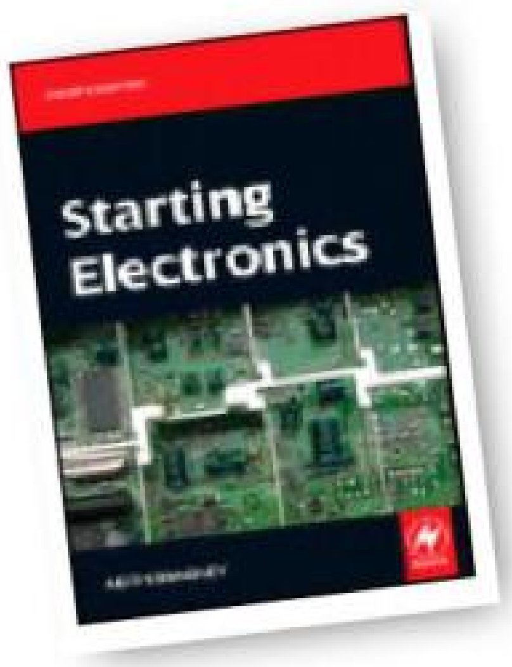

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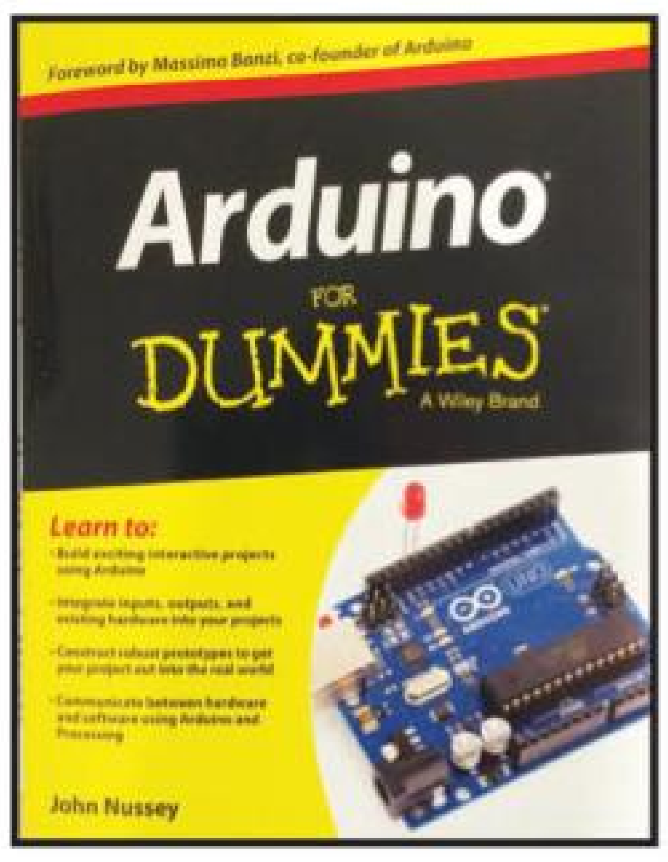
Teach-In 2016

Exploring the Arduino



ARDUINO FOR DUMMIES

John Nussey

Arduino is no ordinary circuit board. Whether you're an artist, a designer, a programmer, or a hobbyist, Arduino lets you learn about and play with electronics. You'll discover how to build a variety of circuits that can sense or control real-world objects, prototype your own product, and even create interactive artwork. This handy guide is exactly what you need to build your own Arduino project – what you make is up to you!

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- Kitted out – discover new and interesting hardware to turn your Arduino into anything from a mobile phone to a Geiger counter.
- Become an Arduino savant – find out about functions, arrays, libraries, shields and other tools that let you take your Arduino project to the next level
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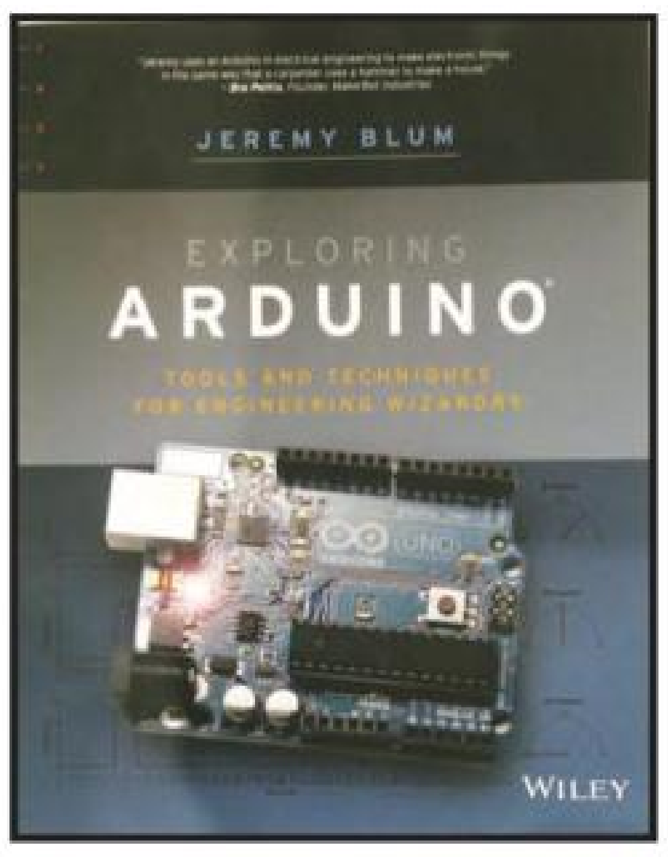

EXPLORING ARDUINO

Jeremy Blum

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Exploring Arduino shows how to use the world's most popular microcontroller to create cool, practical, artistic and educational projects. Through lessons in electrical engineering, programming and human-computer interaction this book walks you through specific, increasingly complex projects, all the while providing best practices that you can apply to your own projects once you've mastered these. You'll acquire valuable skills – and have a whole lot of fun.

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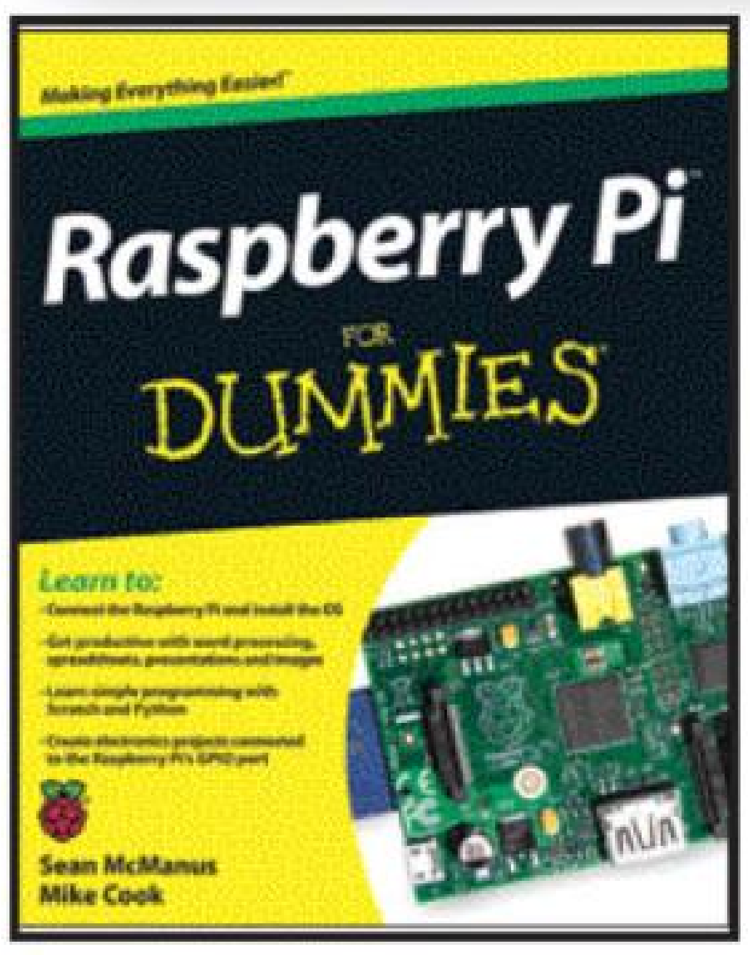
RASPBERRY PI



RASPBERRY Pi FOR DUMMIES

Sean McManus and Mike Cook

Write games, compose and play music, even explore electronics – it's easy as Pi! The Raspberry Pi offers a plateful of opportunities, and this great resource guides you step-by-step, from downloading, copying, and installing the software to learning about Linux and finding cool new programs for work, photo editing, and music. You'll discover how to write your own Raspberry Pi programs, create fun games, and much more! Open this book and find: What you can do with Python; Ways to use the Raspberry Pi as a productivity tool; How to surf the web and manage files; Secrets of Sonic Pi music programming; A guide to creating animations and arcade games; Fun electronic games you can build; How to build a 3D maze in Minecraft; How to play music and videos on your Raspberry Pi.

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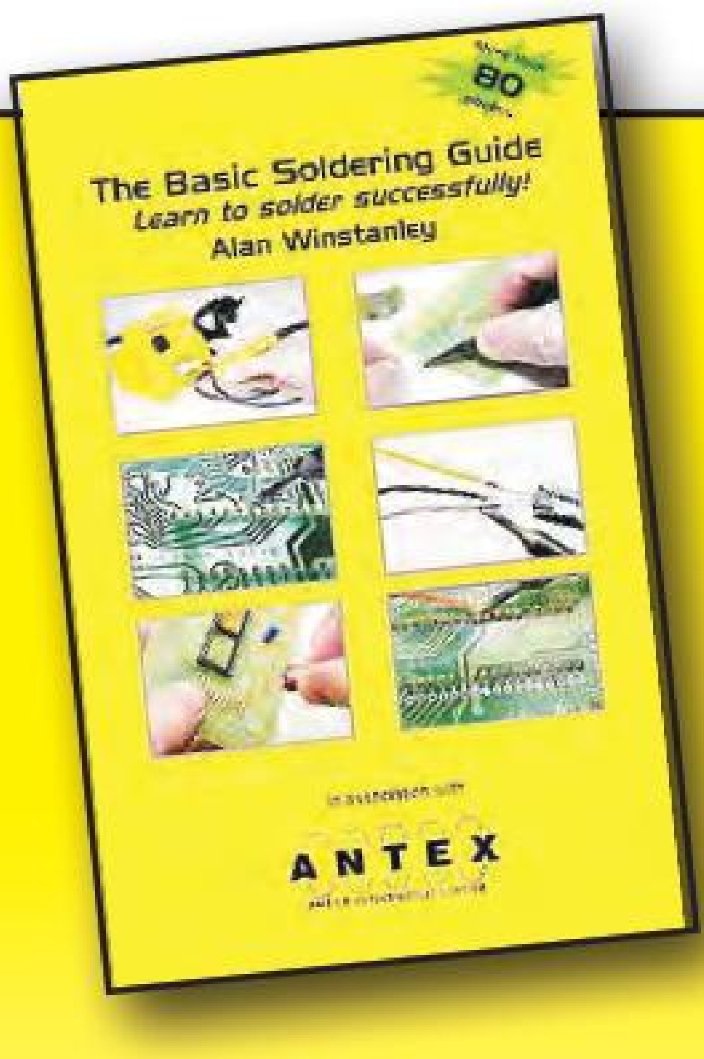

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READOUT

Matt Pulzer addresses some of the general points readers have raised. Have you anything interesting to say?
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All letters quoted here have previously been replied to directly

Email: editorial@wimborne.co.uk

☆ LETTER OF THE MONTH ☆

Micromite for Macs

Dear editor
As a PIC hobbyist I found the articles (*EPE*, February to April 2017) introducing the Micromite fascinating and couldn't wait to get the bits and try it out. It seems a great leap forward to encourage those who would like to use PICs for their excellent facilities but are put off by the need to understand the complexity of these devices and to learn either assembler code or the powerful, but difficult C language.

Inevitably, the system described by Geoff Graham is based around using the most popular computer set up – PCs with Windows. However, I am part of the 'heretical' minority that uses an Apple Mac computer. I investigated how best to use a Mac to develop Micromite programs, and I hope the following information will be useful to others. It is based on using a Mac with OSX Sierra v10.12.4 and an Apple Magic keyboard.

In my investigations I used a CP1202 USB-to-serial module, as described in the article. The driver was downloaded from the chip's designers – Silicon Labs. It installed on my Mac in the usual easy way. Correct installation can be verified with the module plugged in either by looking at the USB section under 'About this Mac' or by typing `ls /dev/tty.*` at the Terminal command prompt. The driver has the snappy name of SLAB_USBtoUART, but will be different if you have chosen a driver from another source.

The first issue to decide is which terminal emulator to use. I tried several of the free ones, but I found that function keys F1 to F4 do not work with the Micromite. Fortunately, the Mac has its own in-built emulator called 'Terminal'. In this emulator it is possible to alter the mapping of the function keys, and this proved the best option. To set up the function keys correctly for the Micromite you need to launch Terminal and select the Keyboard tab under **Preferences>Profiles**. Double click on F1 to F4 and edit the escape sequences to the following:

```
F1       \033[11~
F2       \033[12~
F3       \033[13~
F4       \033[14~
Shift-F3 \033[25~
```

Note that the backspace key cannot be used for editing these fields – a button on the form has to be pressed to delete a character. Making the Shift-F3 alteration is a bit tricky. Make sure to select 'Shift' in the modifier box and then edit the escape sequence from another function key after copying and pasting it.

With the USB-to-serial module and the Micromite hooked up as described in the article, connection to the Micromite can be made by typing the following at the Terminal prompt:

```
screen  /dev/tty.SLAB_USBtoUART  38400
```

Here, screen invokes the serial emulator and the parameters are the driver location and the desired baud rate.

To avoid having to type the screen command each time it can be automated. Type the screen line above into the Run Command box in the shell tab of **Terminal>Preferences>Profile>Startup**, ensuring that the 'Run Command' and 'Run inside shell' boxes are ticked.

On launching, Terminal will connect immediately to the Micromite. The serial connection is closed by typing Ctrl –a–\ or Ctrl–A–\ (ie, pressing Ctrl a (or A) and \ simultaneously). This should be done at the end of the session before closing Terminal.

Mac users familiar with the underlying UNIX nature of the OSX operating system will also know that the `screen` command line above can be saved in a plain text file without an extension, the permissions changed to allow execution and moved to `/usr/local/bin/`. Typing the name of the file then executes the screen command.

Everything should now work as described in the articles.

If the Micromite editor is used exclusively to create and edit the program there is the danger that if the PIC is accidentally 'fried' then not only will the chip be lost, but also the only version of the developed program – obviously back ups are needed. The `screen` command has a log function, which will capture all terminal activity into a log file. This can be used in two ways. Consider the command written as:

```
screen –L  /dev/tty.SLAB_USBtoUART  38400
```

The –L parameter switches on logging. Alternatively, while connected to the Micromite, the sequence Ctrl –a H (Ctrl –a or A pressed simultaneously, released and then H (not h) pressed) will toggle logging on and off. So at any time, logging can be invoked, the program LISTed and logging toggled off. The result is that the program text will be appended to a file named **screenlog.n**, where **n** is the number of the screen and will usually be 0. From time to time this file can be edited to remove old versions of the program.

I prefer to use an external editor and use the autosave feature of the Micromite to transfer the program. A popular editor for Mac programmers is TextWrangler (free from the App Store), which is very powerful and can be customised to suit individual languages. This is produced by Bare Bones Software, and I am indebted to Patrick Woolsey of that company for his help in producing my customisation for Micromite Basic.

TextWrangler can be customised after installation by downloading the file **MicromiteBasic.plist** from the Language Module Library found in the BBEdit support page on the **barebones.com** website. This is then moved into the **Application Support>TextWrangler>Language Modules** directory. To use it, launch TextWrangler, type the first line and save the file with the extension **.mmb**.

This extension tells TextWrangler that this is a Micromite Basic file and will apply the appropriate customisations.

Richard Hinckley, by email.

Matt Pulzer replies:
Fantastic work Richard! While Windows-based PCs definitely rule the roost, there are more and more Mac users and it's great to be able to offer them a straightforward route into using the wonderfully versatile and user-friendly Micromite. I have forwarded your excellent letter to Geoff Graham, who is always keen to hear Micromite user feedback.

PIC n' Mix fan!

Dear editor
Thanks for an excellent magazine, which I have been buying for years. I just wanted to say that I hope *PIC n'Mix* is not going to frizzle out like it did in *Elektor* magazine.

Please provide more of the same because there is a huge hole in this area that is not covered well by technical books.

I would particularly like more information on loading/sourcing and interfacing; when to use FET or BJT drivers; when a buffer may need to be used with an output from a DAC or into the input of an ADC of a PIC, or any of the other peripherals. (The data sheets do not mention, or I can't find it.)

I am also interested in very-low power circuits and determining when it would be good to use an external oscillator.

I'd like to see some more good projects, such as making a very accurate and sensitive thermometer using a PIC, and how to calibrate it.

How to choose a particular PIC out of the many hundreds available would be very helpful.

Perhaps some advice on when to move from 8-bit to higher n-bit PICs – and an introduction to the modern 32-bit PICs.

Maybe we could have a mention about modern SoCs (system on a chip) like the ADuCM360 by Analog Devices. There is nothing available at a low level here to help 'beginners' make a start.

Last, I do hope a few more readers show interest, as I know you have to publish what is popular.

Ewan Cameron
Electronics Technician
University of Cambridge
B.Eng (Hons) Communication Engineering?

Matt Pulzer replies:
Thank you for such an enthusiastic – and helpful – email.

It's always great to be appreciated, but what we really like is guidance on what readers would like to see in the magazine I can assure you that PIC n' Mix *is here to stay. The current PIC introductory series is drawing to an end, but not* PIC n' Mix, *and we are currently planning future topics and projects.*

I will forward your most helpful comments to PIC n' Mix *author Mike O'Keeffe and I am sure we will cover some of the ideas you mention over the next 12 months or so.*

PICs, and microcontrollers/microcontroller systems in general are of course a vital part of modern electronics, which is why we cover not only PICs, but also Raspberry Pi, Arduino, BBC micro:bit and the excellent Micromite, which is of course based around a 32-bit PIC. You can be certain that these and newer iterations as they come down the line will always be extensively covered in EPE.

Last, but not least, towards the end of the year we are hoping to start a new column on the Internet of Things (IoT), which will certainly be microcontroller oriented.

EPE diagram software

Dear editor
I've been a reader of *EPE* magazine for some years now and I have always been impressed by the clarity and quality of the circuit diagrams published in the magazine. I wonder if you could let me know what CAD program you use to produce the diagrams?

Phil Buckley, by email

Matt Pulzer replies:
The majority of the project diagrams are produced using CorelDraw and the rest, for example in Circuit Surgery, PIC n' Mix *and* Audio Out, *are drawn with Adobe Illustrator. (Strictly speaking, these are 'vector graphics' packages and not 'CAD'.)*

I used to work with CorelDraw and it is an excellent package. However, when I changed PC systems from a Windows-based machine to an Apple Mac, I had to stop using CorelDraw because Corel no longer made an OSX-compatible version. At that point I started to use Adobe Illustrator. I have used both and can recommend both, but personally I prefer Illustrator.

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Next Month

SEPTEMBER '17 ISSUE ON SALE 3 AUGUST 2017

Compact 8-Digit Frequency Meter

This compact, fully auto-ranging *8-Digit Frequency Meter* is ideal for hobbyists and technicians, for general servicing and for laboratory use. It will even cover the 6m amateur band. Accurate calibration can be done without any specialised equipment.

Micromite Plus Explore 100

The *Explore 100* expands on the *Micromite Plus Explore 64* described last month, adding more I/O pins, two slots for mikroBUS Click expansion boards and provision for an RTC, USB-to-serial adaptors and a PS/2 keyboard socket. Plus, it connects directly to a 5-inch touchscreen for stunning graphics. Use it as a fully integrated computer or advanced embedded controller.

Low-cost Attenuator

If you like to build your own signal generators for audio and radio frequency work then a recurring problem is how to make a good output attenuator. Traditional attenuators can be huge, expensive and use dozens of weird-value resistors. This project show you how to make a wide-range reasonably accurate attenuator built with easy-to-find components on a single wafer switch that fits neatly into a small space!

Teach-In 2017: Introducing the BBC micro:bit – Part 4

In next month's final *Teach-In 2017* we will be bring this brief series to a conclusion with a look at micro:bit communications. Our practical project will make use of the micro:bit's inbuilt Bluetooth Low Energy (BLE) interface.

PLUS!

All your favourite regular columns from *Audio Out* and *Circuit Surgery* to *Electronic Building Blocks, PIC n' Mix* and *Net Work.*

Content may be subject to change

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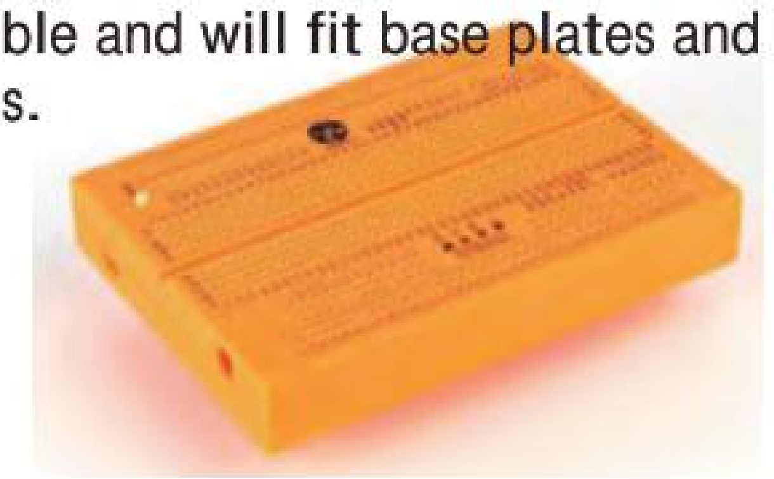

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